Popular Astronomy.

Vol. XXIX, No. 4 APRIL, 1921. Whole No. 284

MEASURING THE STARS WITH THE INTERFEROMETER.

By H. C. WILSON.

Again the seemingly impossible has been accomplished! The diameter of a star has been directly measured.

For a number of years astronomers have, by indirect methods, been able to measure the dimensions of a few of the stars. As is well known the disk of a star is too small to be directly measured with the largest existing telescope, being wholly masked by the much larger spurious disk at the center of the stellar image which is produced by the interference of light coming from the different parts of the objective lens or mirror.

At most the real angular diameter of a star as seen from the earth can be only a very few hundredths of a second of arc. The sun, if removed to the distance of the average first magnitude star, would subtend an angle of only 0".001, which is far below the limit of direct measurement with any telescope. So far as we know, none of the stars are enormously more massive than the sun, so that if they are anywhere near the same density as the sun their angular diameters must be exceedingly small,—in the thousandths of a second or less. Even the "giant" stars, those of very low density combined with great brilliancy, have not exhibited disks recognizably larger than the spurious "diffraction" disk in the telescope image.

It has seemed, therefore, a hopeless task to measure the diameter of a star directly. In the case of spectroscopic binary stars, revolving doubles whose components are too close together to be separated with the telescope, it has been possible, by measuring the radial velocities repeatedly, to construct their orbits and so to get limiting values of the masses and sizes of the component stars. In a few cases, where the orbits are edgewise to us, so that the components eclipse each other periodically (variable stars), by combination of all the different kinds of data obtained, the actual diameters of the stars have been calculated. These have all been of approximately the same order of size as the sun.

Professor A. S. Eddington, of the Cambridge Observatory, England, in his opening address as president of Section A (Mathematical and Physical Science), delivered at the Cardiff meeting of the British Association on August 24, 1920,* uttered this prophecy, remarkable in

*Eddington, A. S., The Internal Constitution of the Stars, *Nature*, London, **106**, 1920, (14-20).

the light of the actual measures which followed so soon after: "the star with the greatest apparent diameter is almost certainly Betelgeuse, diameter 0″.051. Next comes Antares 0″.043. Other examples are Aldebaran 0″.022, Arcturus 0″.020, Pollux 0″.013. Sirius comes rather low down with diameter 0″.007."

It is, therefore, with a great deal of surprise and interest that astronomers receive the recent announcement from the Mount Wilson Observatory of the direct measurement of the diameter of α Orionis (Betelgeuse), and the enormous diameter found for the star, 240,000,000 miles. The measured angular diameter comes out 0″.046 instead of 0″.051 as predicted by Eddington.

Betelgeuse is thus one of the giant stars, as its brilliance might lead us to expect, 260 times the diameter of the sun, 17,000,000 times its volume. If its center were imagined to be placed at the center of the sun its surface would be almost as far out as the orbit of Mars. If its density were the same as that of the sun its mass would be 17,000,000 times as great. On the other hand, if its mass is not many times greater than the sun's, its density must be exceedingly low, far rarer than the earth's atmosphere. We may possibly think of Betelgeuse as at a stage of development corresponding to that of the sun when it extended out to the orbit of Mars.

The method used in measuring the diameter of Betelgeuse was suggested by Professor A. A. Michelson, Director of the Ryerson Physical Laboratory of the University of Chicago, as early as 1890, but for some reason little attention was paid to it by astronomers, possibly because they were so accustomed to the effects of "bad seeing" that it seemed that such a delicate method could never be used. Professor Michelson himself applied the method, at the Lick Observatory in 1891, to the measurement of the diameters of the satellites of Jupiter, but nothing more was done until August 25, 1919, when Professor Michelson made some experiments with the 40-inch Yerkes telescope which seemed to indicate that the method was independent of the character of the "seeing,"—that it could be used in poor as well as in good "seeing." This result was verified in September, 1919, when on invitation of Director George E. Hale the test was applied to the 60-inch and 100-inch reflectors of the Mount Wilson Observatory. The interference fringes upon which the method depends were remarkably clear and steady even when the star images were "boiling" so badly that the "seeing" was estimated at 2 on a scale of 10.

It was decided then by Dr. Hale to give the method a thorough trial with the 100-inch reflector and, as it appeared that an aperture much larger than 100 inches would be required for effective work in measuring stellar diameters, it was decided to apply the method first to the measurement of a double star with components too close to be measured by the usual method. Capella was chosen for the first trial, being a spectroscopic binary with components approximately 1/20

second apart, with fairly well known orbit and parallax, but not separable with the largest telescope.

By a modification of the method suggested by Michelson, which is fully explained by Dr. J. A. Anderson in *Contributions from the Mount Wilson Observatory,* No. 186, Dr. Anderson, during the winter of 1919-1920, obtained a series of measures of Capella which show a surprising degree of accuracy, the distance agreeing with those computed from the elements of the orbit within 0″.0001 and the position angles within less than 1°. The results are compared in the following table:

Date	Distance		Position Angle	
	Observed	Computed	Observed	Computed
	″	″	°	°
Dec. 30.6, 1919	0.0418	0.04180	.....	153.9
Feb. 13.6, 1920	0.0458	0.04583	5.0	4.6
14.6	0.0451	0.04506	1.0	1.0
15.6	0.0443	0.04430	356.4	357.3
Mar. 15.6	0.0505	0.05050	242.0	242.4
Apr. 23.6	.....	0.04391	107.0	107.2

The position angle was observed roughly on Dec. 30 as 148° ± 10°. The distance measured on April 23 was 0″.0402, but was vitiated by the blue background of the sky, the observation being made in strong daylight. The elements which Dr. Anderson gives for the orbits of the components of Capella are the following, the parallax being taken as 0″.0600:

Period	P = 104.006 days
Periastron time	T = J.D. 2,422,387.9
Sum of semimajor axes	$a_1 + a_2$ = 0″.05249 = 130,924,000 kilometers
Eccentricity of both orbits	e = 0.016
Angle node to periastron	ω = 117°.3
Inclination of plane of orbit to line of sight	i = 140° 30′
Position angle of ascending node	$\Omega\Omega$ = 45° 55′

From these elements it appears that the components of Capella are revolving about their common center of gravity in orbits like that of the earth around the sun, except that they are not so far apart as the earth and sun, their average distance being about 81,000,000 miles. The actual sizes of the components are not determined, but Dr. Anderson says that "the complete disappearance of the interference bands showed that the component stars are of equal brightness." The masses come out 4.62 and 3.65, respectively, in units of the sun's mass.

The method used in these remarkable measures is based upon the principle of the interference of light. Briefly it consists in utilizing, instead of the whole aperture of a telescope, only two narrow portions at the opposite ends of a diameter of the objective lens or mirror.

Those who have used a good telescope will know that the image of a star, when the seeing is good, consists of a small central disk surrounded by a series of circular rings, alternately dark and light, fading out quickly with increasing distance from the center of the image. This

"diffraction pattern" of the star image is produced by the interference of light waves coming at different phases from the different parts of the objective, and is perfect only when the source of light is practically a point. When the light from a point source is received through two narrow parallel portions of the objective, the diffraction disk is increased in size, and an interference pattern is projected upon it, consisting of a series of parallel equidistant bands. This will be true no matter how far apart the parallel apertures are if the light source is a point, and will hold also for a two-point source (double star) so long as the angular separation of the two points is so small that the light waves coming from them enter the parallel apertures of the objective much less than a half wave-length apart. When the angle is sufficient to make the difference in wave phase at the two apertures equal to a half wave-length, the bright bands from the one source will fill up the dark bands from the other, so that all will be bright; the "interference pattern" will disappear, wholly if the sources are equal in brightness, partially if they are unequal.

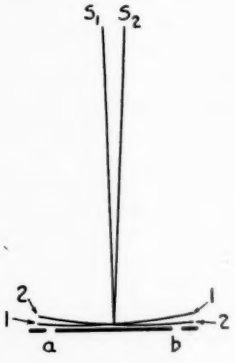


FIG. 1

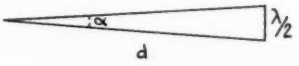


FIG. 2

How this will enable one to determine the angular distance between two stars can perhaps be explained by the use of diagrams. Let S_1 and S_2 in Fig. 1 be two sources of light, very distant stars, such that the angle α between them is very small. Let the curves 11 and 22 be the wave fronts from these sources as they are about to enter the apertures a and b in the occulting disk at the telescope. (The occulting disk may be either in front of the telescope or anywhere between the objective and the eyepiece, provided that the apertures a and b be within the cone of rays and on a diameter of the cross-section of the cone.) In the case of the stars the wave fronts 11 and 22 will be practically planes, out to any usable distance between the apertures, and the angle α between the planes will be the same as that between the stars. Then we may use Fig. 2 in order to derive a formula for cal-

culating either α, or d, or $\Delta\lambda$, if the other two of them are known. Since α is very small

$$\alpha : 206265'' :: \Delta\lambda : d. \quad (1)$$

In order to measure an unknown α the apparatus is constructed so that the distance d between the apertures a and b may be varied, and capable of accurate measurement. The whole occulting disk should be rotated so as to bring the apertures into a line parallel to that joining the stars. When the apertures have been separated until the interference fringes disappear, the distance d becomes known by measurement and $\Delta\lambda$ is known to be one-half wave-length. Then

$$\alpha = 206265'' \lambda/2d. \quad (2)$$

If the occulting disk is placed at a distance x from the focal plane of

FIG. 3

the telescope, as in Fig. 3, d is made smaller in the ratio of x to f, the focal length of the telescope, so that formula (1) must be written

$$\alpha : 206265'' :: \Delta\lambda : d\,f/x \quad (3)$$

and formula (2)

$$\alpha = 206265'' \lambda\, x/2d\, f. \quad (4)$$

As λ, the wave-length of light, is usually expressed in units of the ten millionth of a millimeter, it is most convenient to express the measurements of d, x, and f, in millimeters, and, as λ varies with the different colors of light, the problem cannot be solved completely without knowing what wave-length is most effective upon the eye, or rather what is the average of the wave-lengths which affect the eye of the individual observer when focussing the particular telescope employed. This wave-

length is somewhere in the vicinity of $\lambda = 5500$ ten-millionths of a millimeter, or 0.00055 millimeters. Adopting this value for λ, formula (2) becomes approximately

$$\alpha = 56''.7/d \qquad (5)$$

where d is the number of millimeters between the centers of the apertures a and b in front of the objective; and formula (4) becomes

$$\alpha = 56''.7\, x/f\, d \qquad (6)$$

when the apertures are near the eye-end of the telescope. The method of reduction is thus exceedingly simple.

For practical use in the search for and measurement of double stars whose components are invisible, Messrs. Pease and Anderson devised an apparatus attachable to the eye-end (or side) of the 100-inch reflector with the "interferometer" about 28 inches inside the Cassegrain (134 ft.) focus of the telescope. The whole apparatus can be rotated easily, the position angle being read from a large graduated circle. The apertures of the interferometer are adjustable in width and their distance apart can be varied quickly by means of a micrometer screw. The process of observation is, after adjusting the widths of the parallel apertures to give the best visibility of the fringes for the star under examination, to rotate the apparatus, noting the angles where the fringes are least and most visible. If the distance between the apertures is greater than that required, there will be four position angles where the fringes will disappear or have a minimum visibility, according as the two components of the star are equal or unequal in intensity, these being symmetrical with reference to the line joining the two components, viz. at $p \pm \theta$ and $p + 180° \pm \theta$. The correct distance d is then the measured distance multiplied by $\cos \theta$.

In the measurements of Capella Dr. Anderson says: "As a rule, a complete observation included three complete rotations of the interferometer for each of three values of d, making a total of thirty-six readings of position angle. The values of d were chosen so that θ, as defined above, should lie between 30° and 50°. Under these conditions and with reasonably good seeing the probable error of a single reading should not exceed 3°. It is the author's opinion that with a little practice a good observer will be able to reduce the probable error of a single setting to about 1°. The corresponding error in distance is about 1.8 per cent. The time required for a complete observation was about one hour, but it is reasonable to expect that when one becomes accustomed to observations of this kind no more than fifteen minutes will be required."

If the distance between the two apertures of the interferometer is less than that required to determine the angle between the stars, and not too much less, the fringes will not disappear but there will be two maxima and two minima of their visibility, and by determining the degree of visibility at regular intervals of position angle, say every 15°, it may be possible to determine the position angle of the components.

Even the correct value of d may be approximately determined by repeating the observation with two other values of d, suitably chosen, although the aperture of the telescope may be too small to permit the interferometer apertures to be set at the correct distance.

For the measurement of the diameter of a star the method just described cannot be used. Rotating the apparatus should produce no change in the aspect of the fringes from a single star. There remains only the process of directly varying the distance between the apertures of the interferometer. In the course of the experiments at Mount Wilson no star was found, of the bright ones which were supposed to be single, for which the fringes disappeared when the apertures were separated to the widest extent permitted by the 100-inch telescope. Betelgeuse showed perceptible diminution of the fringes, indicating that it was not far beyond the reach of the 100-inch. But that base line was too short!

The next step, which was carried out by Mr. Francis G. Pease, was to replace the occulting disk with its parallel rectangular apertures, by a beam 20 feet long attached to the upper end of the 100-inch telescope, carrying four circular mirrors each 6 inches in diameter, two fixed in front of the telescope, making angles of 45° with its axis, and two to be placed parallel with these, facing them, at any desired distance along the beam.

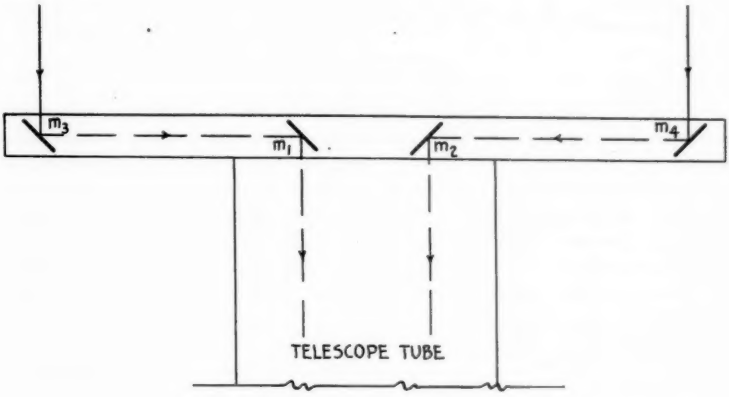


FIG. 4

The base line d can thus be extended beyond the aperture of the telescope as far as desired, limited only by mechanical difficulties connected with the structure of the telescope and dome, and of keeping the mirrors in constant relative positions.

In the case of Betelgeuse (α Orionis), which was successfully measured by Mr. Pease on the night of December 13, 1920, the mirrors m_3 and m_4 were found to be 10 feet apart when the fringes of the star

image disappeared. The definition that night was excellent and the observer saw no trace left of the fringes as long as he looked, although when the apparatus, with the same adjustment, was turned on a neighboring star, the fringes were clear cut and steady.

As 10 feet is equal to about 3032 millimeters, the angle α comes out $56''.7/3032 = 0''.0187$. That which is measured in this case, however, is not the diameter of the stellar disk but the distance between what we may call the centroids of luminosity of the two halves of the disk.

If we assume the centroids to correspond to the centers of gravity of semicircular laminae we find them to be at approximately 0.41 of a radius on either side of the median line of the disk, so that the distance between them is only 0.82 of a radius. To obtain the diameter we must therefore double the measure and multiply it by the reciprocal of 0.82, which is about 1.22. This factor 1.22 agrees with that obtained by Michelson, by an entirely different and more rigorous method, and is applicable to an uniformly illuminated disk. In case the star has an extensive envelope of absorbing gases the outer parts of the disk will be darker and the centroids of luminosity will be closer together; hence the multiplying factor must be larger than 1.22.

We have therefore as a minimum for the angular diameter of Betelgeuse $2 \times 0''.0187 \times 1.22 = 0''.046$. It may be considerably greater.

FIG. 5

When the angular diameter has been measured, the diameter in astronomical units (the earth's distance from the sun) is easily obtained by comparing the two long triangles extending from the earth's orbit to the star (Fig. 5). The small angle in the one is the apparent diameter of the star and in the other the star's parallax, or angle subtended at the star by the radius of the earth's orbit.

These triangles are so long and the angles so small that the long sides are sensibly equal and the ends are directly proportional to the small angles opposite them. Therefore

D (diameter of star) : 1 (radius earth's orbit) :: α (angular diameter star) : π (star's parallax)

and

$$D = \alpha/\pi \tag{7}$$

For Betelgeuse the average of the best determinations of its parallax gives $\pi = 0''.018$, whence the diameter in astronomical units is

$$D = \frac{0.046}{0.018} = 2.55$$

As the earth's average distance from the sun is 92,900,000 miles, we have for the diameter of the star

$$D = 2.55 \times 92{,}900{,}000 = 237{,}000{,}000 \text{ miles.}$$

or, in a round number as accurate as the data will justify, 240,000,000 miles.

The question now arises as to how many of the stars have angular diameters large enough to be measured. With the present apparatus attached to the 100-inch reflector it may be seen from the above discussion that the lower limit of measurement is 0″.023 for the diameter of a star.

In the January 1921 number of POPULAR ASTRONOMY, page 31, is given a list of probable star diameters determined by theoretical considerations, by Henry Norris Russell, Director of the Princeton Observatory. (See more extended list by Russell in *Publications of the Astronomical Society of the Pacific*, No. 190, December 1920.) In this list only four, α Orionis, α Scorpii, γ Crucis, and α Tauri are above the limit just given. The field of search seems to be very limited, but as the diameter of α Orionis, which heads the list, comes out a half greater than predicted, it may be that some of the others are also within reach of present means of measurement.

To measure a diameter of 0″.01 would require the mirrors m_3 and m_4 in Fig. 4 to be 46 feet apart, and for 0″.001 they must be 460 feet apart. The latter is of course out of the question with the ordinary form of mounting. But, since the telescope need be only large enough to receive the beams of light from the mirrors m_1 and m_2, it might not be impossible to build an interferometer beam 100 feet long, mounted so as to oscillate east and west through an angle of 30° (permitting observation during two hours), and carrying the telescope as a secondary instead of the primary piece of apparatus. This would make possible the measurement of a star of diameter 0″.005, and would greatly extend the scope of the investigation of the diameters, and thus indirectly of the constitution of the stars.

LATITUDE WITHOUT INSTRUMENTS.

By RUSSELL W. PORTER.

"Not within a mile of the truth" usually means that something or other lies very far from the mark. Locating ourselves within a mile of the truth on this immense globe of ours would, however, be considered a pretty close approximation. To do it with only a string, this approximation would seem to be a remarkably close one.

Two winters ago a good friend—William Brooks Cabot of Boston—well known for his exploratory work in Labrador, suggested that latitude could be determined in the field without an instrument of precision. He deplored even the addition of a pocket sextant and horizon to a camper's pack where dead weights must be shaved to a minimum: that the tools irreducible to the explorer—a knife, hatchet

and fishline—together with nature's available materials, would suffice to obtain latitude within a mile. He had not put the theory into practice, however.

And the writer, doubting that any such accuracy could be reached, put the method to the test. He was greatly surprised, after several false starts, and hitting luckily at last on a novel expedient, to find that latitude could be obtained with a steel tape to well within a statute mile: time (and hence longitude) correspondingly.

The problem resolves itself into the measurement of a vertical angle. In Todd's "New Astronomy," page 82, is described a simple way of finding one's latitude. It obtains the zenith distance by allowing a beam of sunlight to fall on a graduated arc oriented in the observer's meridian. It will probably give one's latitude to the nearest degree.

If now we take the simple case of the sun on the equator at noon, and suspend a weighted line BC from any convenient support, and from its lower end stretch another line AC to our eye when it sees the sun and the point B in line, we have formed a right angle triangle in which the angle A B C will be our latitude. This statement is made clear in the smaller diagram, where an observer at A finds that the angle between his zenith and the equator (in this case a very distant object lying in the plane of our equator) will always be his latitude.

Now in this triangle A B C the hypothenuse B C is readily and accurately determined. The plumb line may be suspended from the limb of a tree or from a nail driven into the top of a porch post, or on the corner of a house. A good working length is about ten feet. Since the angle we desire is angle A B C, if we can measure the side A C then the sine of this angle is at once found and the angle may be taken directly from a table of sines.

It now remains to work out a convenient means of measuring this sine, and the writer has found that the following procedure gives the most satisfactory results. While a fish line or cord can be used, since the ratio only of A C to B C is required, yet more accuracy is attained with a small pocket steel tape whose feet are divided into tenths and these again into tenths. As these last divisions may be estimated to tenths, we obtain readings to one thousandth of a foot.

The point C at the lower end of our plumb line is next fixed in a secure manner.

I have found it practical to bring the end of a sapling or small log up to the base of the tree when in the wilds, and to drive a nail into the butt opposite to some whole division on the tape. This end of the plumb line is of course already provided for the nail if we use a house corner or porch post.

The other end of the sine line, at A, can be found by the use of a screen or target in which a small hole has been bored, and the target capable of being slid along the tape to any desired position. A sketch of this is shown in the figure. For use with the sun a piece of colored

glass must cover the pin hole to protect the eye, but with the stars at night an ordinary visiting card suffices.

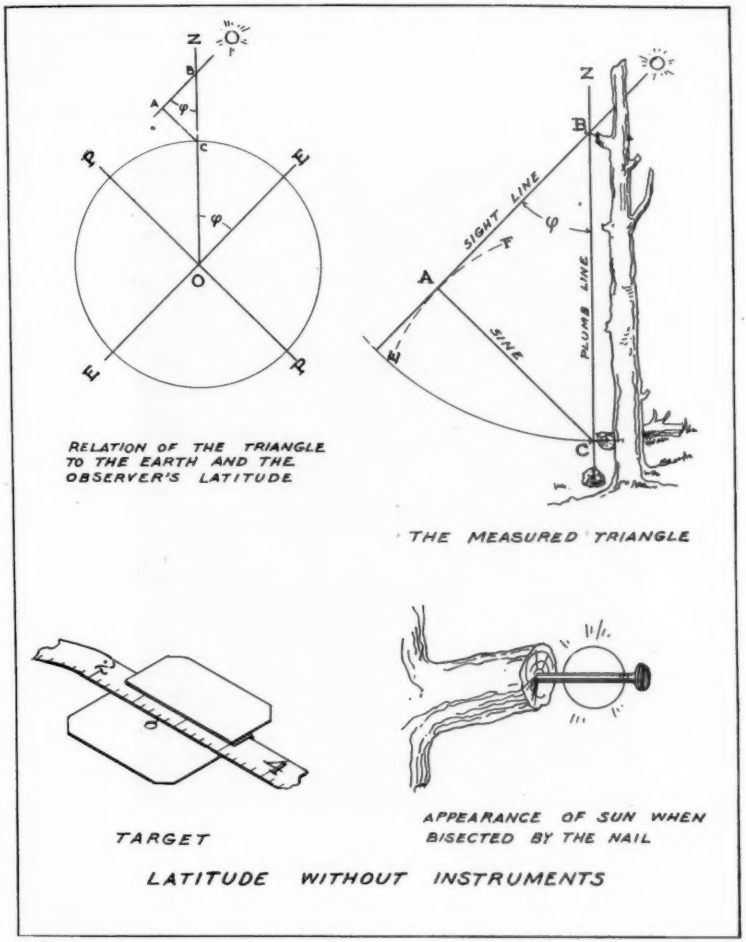


FIG. 1.

If now the buckle of the tape is hooked over the nail at C and the tape drawn taut over the head of the observer as is shown in one of the photographs, a position will be found where the nail at the upper end of the plumb line is seen to just bisect the sun's disc. The appearance then will be shown as in the figure, and the head must be moved up and down and the target shifted until the sun is bisected

with the ***minimum length of tape.*** That is, a position will be found as the target sweeps through the arc E F, where the sun seems to rise towards the nail, remains stationary a moment and then falls away. It is at this middle position that the tape is at approximately right angles to the sight line A B, and the length of the sine may then be read off on the tape just opposite the pin hole.

With a little experience this operation of getting the eye, the target,

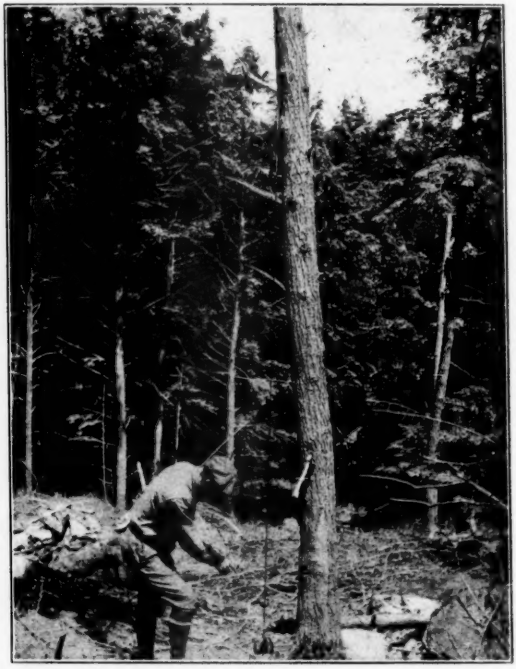


FIG. 2. DETERMINING THE HYPOTENUSE B C OF THE TRIANGLE WITH A PLUMB LINE.

the nail and the sun all in line, becomes an easy one, and if you have been careful in locating these three points of our triangle the observation is finished, and if your plumb line is ten feet, and the sun is on the celestial equator, the angle corresponding to the sine you have measured is your latitude, without further computation.

The sun, however, is on the equator or is "crossing the line" as navigators say, but twice a year—in March and September. Its distance north or south of this position (that shown in the figure) is given for each day in the almanac. It is called the sun's declination. If it is north of the equator--between March and September—this declination

must be added to the angle obtained by observation in order to obtain the latitude.

One other small correction is necessary—that caused by refraction. The sun is never really as high as we see it in the sky, because the light coming from it to the eye is bent down on passing through our atmosphere. This correction for the sun in our latitude never amounts to over two minutes of arc: in summer it is less than one minute. By

FIG. 3. TAKING THE OBSERVATION. NOTE HOW THE TAPE IS HELD TAUT WITH THE RIGHT HAND.

reference to the figure (1) it will be seen that the angle observed viz. ABC is the same as ZBS: that is, we have measured the angle from a point directly overhead down to the sun—what is known as the zenith distance. This angle, on account of the refraction, is too small, and therefore this correction is always to be added.

That is all there is to it. The steps are as follows:

1st. Fix two points ten feet apart with the plumb.

2nd. Find the angle between this line and a sight line through the upper point to the sun by measuring its sine.

3rd. To this angle add the correction due to refraction, and apply

the sun's declination from the almanac—plus if north and minus if south of the equator.

The result is the latitude.

The above description has been written especially for the young

FIG. 4. THE LOWER END OF THE HYPOTENUSE C.

student who would know something of practical astronomy, but who fears it is beyond him; fears that there is something very mysterious about it, involving higher mathematics, years of application and the use of delicate and expensive instruments beyond his reach. The purpose of this article is fulfilled if it stimulates some one to put his knowledge of plane geometry to practical use, and leads him to further inquiry.

To the reconnaissance surveyor, and to the astronomer it may be of interest to know that this method of determining latitude and time is susceptible of considerable refinement. For instance, the triangle may be referred to the centers of the two nails at the ends of the plumb line, and the center of the pin hole of the target. The buckle at the end of the tape may be deformed so that the tape divisions will read from the nail centers. The diameter of the pin hole cannot be much less than 2 mm if stars are used. With the sun somewhat less than a

millimeter hole is about right. The bisection of the sun's disc seems to be reliable to less than a minute of arc. An error of one thousandth of a foot in the sine for a summer meridian altitude in our latitude affects the angle sought about half a minute of arc. The following

FIG. 5. THE OBSERVER IS HERE SHOWN WITH THE TARGET SO PLACED ON THE TAPE THAT HE SEES THE SUN BISECTED BY THE NAIL ON THE TREE AT THE UPPER END OF THE PLUMB LINE.

circummeridian zenith distances on the sun, using a theodolite to check the angles are submitted.

LATITUDE FROM CIRCUMMERIDIAN ALTITUDES OF THE SUN AS DETERMINED BY TAPE LINE.

SPRINGFIELD, VERMONT, AUGUST 8, 1920.

75th Mer. Watch Time			Tape Reading	Zenith Distance		Z. D. Red. to Meridian		Latitude		Res.
h	m	s	mm	°	′	°	′	°	′	′
11	41	30	1457.5	27	17.4	27	12.8	+43	19.8	−1.3
	47	20	1453.0		11.9		11.1		18.1	+0.4
	52	10	1452.5		11.3		11.3		18.3	+0.2
	56	50	1453.0		11.9		10.2		17.2	+1.3
0	2	30	1459.0		19.2		12.0		19.0	−0.5
	8	0	1464.5		25.9		11.4		18.4	+0.1
Length of plumb line, 3179.0mm								mean	43° 18.5	
Latitude by theodolite,									43 18.3	

The first two columns represent the observations. The third and fourth give the steps in reducing these observations to the meridian. In the fifth column the corrected sun's declination is applied, giving six independent determinations of latitude. The last column shows the amounts by which each determination departs from the mean derived latitude.

Finally in a triangle the size of the one described a considerable departure from the right angle at A may be allowed before it disturbs the angle sought by as much as a minute of arc.

The writer attempted a further improvement by placing a totally reflecting prism at A so that the observer could look down the sine at a convenient angle against a dark background (case of the sun). He found that any improvement in convenience of posture was offset by the vibration and shifting of the objects viewed through the prism due to its unstable mounting. Even the pentagon prism proved of little help.

SATURN.

By ALFRED RORDAME.

Saturn, the most charming of celestial objects and without doubt the most often observed,—its soft golden lustre is eagerly sought by the student in the earliest twilight. The planet which, with its glorious ring system and lovely retinue of satellites, in moderate sized telescopes is captivating, becomes in the larger apertures of superlative grandeur and beauty. The vision, no matter how often beheld, never palls and is the one object that compels an exclamation of admiration by the most indifferent beholder.

I well remember my first observation of Saturn through a home-made telescope, a non-achromatic, constructed with a concave eye-piece. It was merely a repetition of Galileo's view, and had I not previously seen engravings of the planet, would have been as sorely perplexed as the great inventor of the telescope himself. With each improved instrument in turn has Saturn to me proven a source of delight, and in the 16-inch Mellish reflector the planet takes on the aspect of a globe of dull gold, while the ring system shows a variety of tints from pearly white through all the shades of yellow to the dusky blue of the crape ring.

I have lately come across an extract from Huyghen's "Systema Saturnium" which plainly shows the difficulties the early observers had to contend with in explaining the puzzling appearances of Saturn's rings as shown in their inferior telescopes. As is well known, Galileo was the first who discovered anything uncommon connected with Saturn. Through his telescope he thought he saw that planet appear like two smaller globes on each side of a large one, and after viewing the planet in this form for two years, he was surprised to see it be-

coming quite round, without its ajoining globes, and sometime afterward to appear again in the triple form. This caused great anxiety to the astronomer, for if he was mistaken on this point all the observations he had made must be open to doubt. He pathetically remarks, "I do not know what to say in a case so surprising, so unlooked for and so novel. The shortness of the time the unexpected nature of the event, the weakness of my understanding and the fear of being mistaken, have greatly confounded me."

In 1614, Scheiner, a German astronomer, published a representation of Saturn in which the planet was exhibited as a central globe with two handles attached to it. A number of other observers, among them Hevelius and Ricciolus published drawings between the years 1640 and 1660 representing the planet with elliptical appendages of various kinds, some of them quite near the truth.

Huyghens, who perceived that the lack of uniformity in these drawings arose from insufficient magnifying power, set himself to improve the telescope and became a master in grinding and polishing object glasses, which he finished with his own hands. He produced lenses of a more correct figure and of longer focal distance than those previously constructed. His first telescope was 12 feet long, followed by one 23 feet long which magnified about 95 times while his best telescope was 123 feet long and magnified 220 times. It was used without a tube the object glass being placed upon the top of a pole and connected by a cord with the eye-piece. With this telescope he discovered the fourth satellite of Saturn and cleared up the mystery of the rings. His admirably clear and correct statement concerning the latter reads: "Saturn is surrounded by a thin, flat ring nowhere touching, inclined to the ecliptic."

After the invention of the reflecting telescope and the achromatic, astronomers began to see the ring system in its true form, and discoveries of the divisions in the ring by Cassini and Encke were followed by the discovery of the crape ring by Bond and Dawes.

A drawing of Saturn made by Dr. Hook at London, June 29, 1666, (Frontispiece) curiously enough shows the existence of the crape ring. He does not mention it in his account of the observation, which was made with an aerial telescope of 60 feet focal length. He evidently was anxious to confirm Huyghens' observations, as he lays stress on the fact that he "could manifestly see that the southernmost part of the ring was on this side of the body, and the northernmost part of the ring behind or covered by the body."

As stated by Huyghens the ring system is inclined to the ecliptic, making with it an angle of 28 degrees and 10 minutes, which accounts for the different aspects under which we see them. The plane of the rings intersect the ecliptic in longitude 168 degrees and 348 degrees. The former point is the ascending node, and the latter the descending node. When Saturn reaches one of these points, the rings will disappear in all but the largest telescopes, showing their extreme thinness

when seen edgewise. The satellite Titan has been seen "like a beautiful bead moving very slowly along a fine golden thread." The ring system was at first supposed to be circular, but it is now generally conceded that the true form of the rings is elliptical.

Clerk-Maxwell in 1857 proved theoretically that the marvelous structure of Saturn's rings is formed out of dense swarms of minute satellites, revolving independently in distinct orbits in periods corresponding to their several distances from the planet. It was not until the year 1895 that the meteoric constitution of the rings was confirmed by means of spectrograms taken by Keeler. The speed was found to be greatest at the inner edge and gradually diminished outward, each part moving with the speed at which a satellite would travel if it were placed at the same distance from the planet. This fact was immediately confirmed by Campbell, Deslandres and Belopolsky.

That the innumerable satellites of which the ring system of Saturn is composed are not in very close proximity to each other is shown by the fact that several instances have been recorded where stars have been seen through the rings, passing through their shadow without altogether disappearing, notably an observation by Barnard in 1892 of a satellite which shone with but slightly diminished lustre. Ainslie, on Feb. 9, 1917, observed an occultation of a small star by the rings of Saturn. The star when first seen appeared to be projected on the extreme edge of Ring B. It passed along the Cassini division and appeared during its passage to be as bright as when clear of the planet. It was afterwards easily seen through ring A, except for two sudden brightenings, the first lasting 10 to 15 seconds, and the second only for about 5 seconds. Mr. Ainslie took these to correspond with Encke's division and another exterior to it. The star was not so bright when passing behind these gaps as when clear of the ring, but was estimated to be twice as bright as when seen through the ring. This observation goes to show that the ring is composed of comparatively minute particles, for if any of them were much more than 200 yards in diameter a perceptible flickering or momentary obscuration would have taken place during the passage of the star behind the ring.

It has been suggested by Serviss that the outer portions of the globe of Saturn may be composed of separate particles of matter in the form of dust instead of the usually accepted theory of a gaseous globe. This suggestion conforms more nearly to the requirements of the theory of Darwin, which postulates a nucleus of extreme density.

It is probable that Saturn may have, beside the nine satellites already known, a number of others revolving around him as a center. In fact meteoric matter may be more abundant in the vicinity of this planet than anywhere else in the solar system, with the possible exception of the immediate neighborhood of the sun.

THE COLLIMATION OF A REFLECTING TELESCOPE.

By ALICE H. FARNSWORTH.

The importance of accurate collimation of any instrument used either for photometric or astrometric work does not need to be emphasized; and it is apparent that in the case of a reflecting telescope, whose optical system must necessarily be disturbed at intervals to allow re-silvering, the problem of finding a precise and rapid method of collimation is an essential one. Such a method must include means for a quantitative determination of the errors due to uncertain factors such as flexure of the tube, or slipping of the mirror in its supports,—errors which are different for different positions of the telescope and remain after the best possible adjustments have been made. A knowledge of the magnitude of such errors and of any changes when either mirror is removed and replaced is necessary if photographic plates taken at different epochs are to be compared.

The method of collimation described in what follows was applied to the 24-inch reflector of the Yerkes Observatory. This instrument has a focal length of 93 inches. See the *Astrophysical Journal* **14**, 217, 1901, for a detailed description of the mounting. It is sufficient to note here that the large mirror is supported in a skeleton tube, at the upper end of which the 6-inch diagonal plane mirror is held in place by four steel bands. This mirror throws the light reflected from the large mirror upon the plate-carrier attached to the side of the tube.

The problem is two-fold: 1) to determine where the optical axis strikes the plate, or, more specifically, to determine the scale readings of the double slide plate-carrier when it is so placed that it receives the optical axis at its center; 2) to make the plane of the plate-carrier normal to the optical axis. The first adjustment is controlled by the screws α and δ (Fig. 1) which give motion to the plate-carrier in right ascension and declination, its position being read from the scales shown in the upper right-hand corner of the carrier. The second

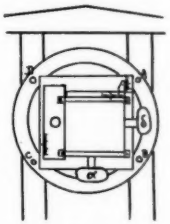


FIG. 1

is controlled by the motion of the collimating screws of the plate-carrier. These consist of four small hollow tubes threaded into the

iron frame of the telescope at the points A, B, C, D. The ends of these tubes rest against the camera plate which is held in contact with them by rods passing through the tubes and provided with nuts at the other ends. The two mirrors are also provided with collimating screws, but adjustment of the plate-carrier is more convenient.

The distant end of the optical axis is located by means of a paper disk six millimeters in diameter close to the center of the 24-inch mirror (M), carrying a pencilled cross indicating its exact center (*m*). The collimating telescope T is one of 18 mm aperture and 115 mm focal length and is provided with rack and pinion for rapid focusing. It is attached to the center of a metal plate P which fits into a plate-holder so that it occupies the ordinary position of the photographic plate. The plate P carries four levelling screws, adjustment of which insures perdendicularity between P and the optical axis of T. A pair of crossed wires fastened just in front of the objective, together with the intersection of cross-hairs (C) in the focus of the eye-piece define the optical axis of T. The two-fold problem previously stated thus becomes one: to place the optical axis of T (AT) in the optical axis of the 24-inch mirror (AM).

For this purpose the relative positions of three points are considered: the center of the 24-inch mirror (defined by cross *m*), the center of the objective of the collimating telescope (defined by cross O), and the reflection of O from M (designated by R). It is evident that the cross O is not directly visible to the observer looking through T, but its direction is located by means of the cross C. Since the light from O has twice as far to go as that from *m*, the focus of T for R and *m* is different. It is found possible to adjust the focus of T so that both are visible at once, though out of focus. The rack and pinion makes it easy to pass quickly from sharp image R to image *m*.

The interpretation of the relative positions of *m*, R, and C for various combinations of tilt and displacement of AT becomes clear by reference to the diagrams. (In the diagrams the apparent position of

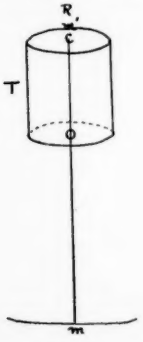


FIG. 2

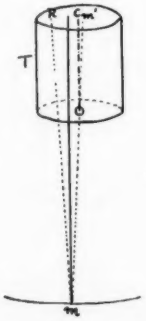


FIG. 3

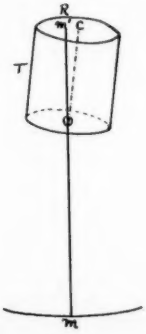


FIG. 4

m in the eye-piece is designated by m'.)

Fig. 2 Ideal case: AT is in AM.
R, m, and C are coincident.

Fig. 3 Displacement only: T is displaced, but AT remains parallel to AM.
R and m are displaced in opposite directions from C, R more than m.

Fig. 4 Tilt only: O is in AM; AT is inclined to AM.
R and m coincide, displaced from C.

Fig. 5 General case: O is displaced from AM; AT is inclined to AM.
a) CO prolonged points to m.
m coincides with C; R is displaced.
b) CO prolonged crosses AM.
R and m are displaced in same direction from C, R more than m.
c) CO prolonged does not intersect AM.
R and m are displaced in opposite directions from C, R more than m.

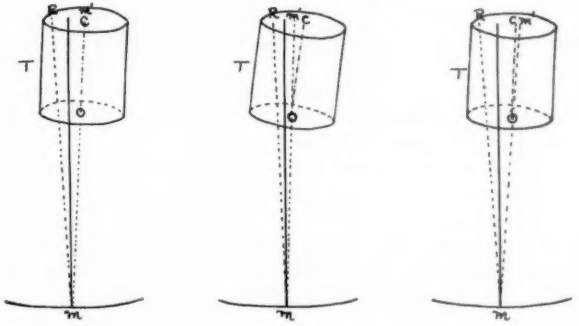


FIG. 5

It is clear that if R and m do not coincide there must be displacement and this error should be removed before attempting to correct for tilt. For R and m coincident, 1) not at C: error is in tilt only, 2) at C: collimation is correct. Since adjustment of tilt may affect slightly the location of O, readjustments should be made until both errors are corrected.

A convenient preliminary adjustment of screws α and δ was made by using a wooden block with a small circular aperture at its center and bringing into coincidence with m the center of the aperture and its reflection. The screws α and δ were then adjusted until R and m coincided, and the collimating screws adjusted until both coincided with C at the zenith. That the reflection of O was caused as shown in the diagrams by that part of the mirror immediately adjacent to m, was demonstrated by covering all the rest of the mirror, when R remained as before. The curves of Fig. 6 show the behavior of R and m for

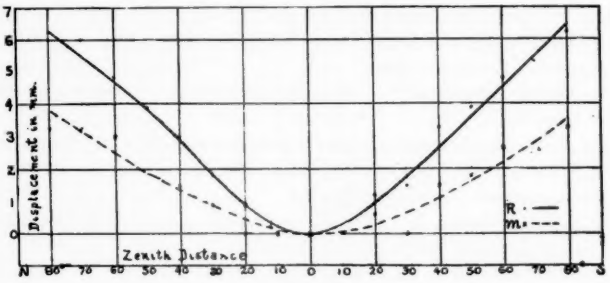


FIG. 6

different zenith-distances, the telescope being east of the pier and in the meridian, and the α and δ scales kept constant at 3.5 and 8.5 respectively. They show an increasing displacement from C as the telescope is moved from zenith distance 0° to 80°; the displacement of R is greater than that of *m* and both are in the same direction. Reference to Fig 5 (b) shows that these are the consequences of a tilt and displacement of AT such that AT produced crosses AM. It is readily seen that flexure of the telescope tube might produce just such a tilt and displacement of AT. Slipping of M in its supports would cause R and *m* to depart from C in opposite directions.

It is a comparatively simple matter to use different scale readings of the plate-carrier for various zenith distances and thus receive AM always at the center of the plate. Fig. 7 shows the curves for hour-angle 0^h, where changes in zenith distance are due entirely to changes in declination. Readings of the α and δ screws when R and *m* are in coincidence are given. The α readings show rather large accidental

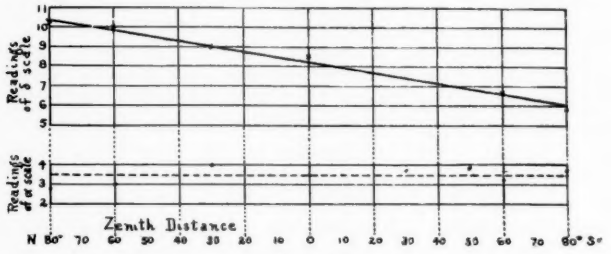


FIG. 7

differences due partly to uncertainty in setting caused by a looseness of the eye-piece tube in the collimating telescope, but no definite progression. The δ readings, on the other hand, progress in a way that would be accounted for by assuming flexure of the tube in a plane perpendicular to the declination axis. When changes in zenith distance are produced by changing the hour-angle, δ being kept constant, scale

readings both in α and δ show change, since a vertical section of the tube is neither parallel nor perpendicular to the declination axis. Table A, for use at the telescope, gives settings of the α and δ screws for those positions of the telescope in most frequent use.

TABLE A.

H. A.		δ	Z. D.		Tel. E		Tel. W	
h	m	°	°		α	δ	α	δ
0	0	+42	0		3.5	8.5	4.2	8.5
		+32	10	S	3.5	8.1	4.2	8.6
		+22	20		3.5	7.8	4.2	8.8
		+12	30		3.5	7.5	4.2	8.9
		+ 2	40		3.5	7.3	4.2	9.1
		− 8	50		3.5	7.0	4.2	9.3
		−18	60		3.5	6.8	4.2	9.4
		−28	70		3.5	6.5	4.2	9.6
0	0	+52	10	N	3.5	8.6	4.2	8.2
		+62	20		3.5	8.8	4.2	8.1
		+72	30		3.5	9.1	4.2	7.9
		+82	40		3.5	9.4	4.2	7.7
		+88	50		3.5	9.6	4.2	7.5
		+78	60		3.5	9.9	4.2	7.4
		+68	70		3.5	10.1	4.2	7.2
0	0	+45	3		3.0	8.5	3.8	8.5
1	50		20		4.0	8.4	3.8	8.5
3	45		40		4.2	8.0	3.8	8.5
5	44		60		4.5	7.5	3.8	9.0
7	0		70		5.0	7.5	3.8	9.0
1	0	+60	20		3.5	8.5	4.0	8.0
4	2		40		4.5	8.0	4.0	8.0
6	55		60		5.0	7.5	4.0	8.5
8	40		70		5.0	7.0	4.0	9.0
6	0	+90	48		5.0	8.0		

In the table each scale division corresponds to a minute of arc on the plate, so that the extent of the wandering of the optical axis is shown directly. In practise settings to within half a scale unit are considered quite close enough.

When the scale readings are such that R and *m* coincide, it is evident that we have the case represented in Fig. 4 where tilt of AT is the remaining error. This error cannot be eliminated since adjustment of tilt for different zenith distances is not practicable. Therefore if the error is not small enough to be negligible it must be allowed for.

TABLE B.

H. A.		δ	Z. D.		Tel. E	Tel. W
h	m	°	°		mm.	mm.
0	0	−18	60	S	3.6	3.3
		−38	80		4.8	4.8
		+78	60	N	3.9	3.6
		+68	80		5.7	5.7
3	10	0	60		3.6	
5	5		80		3.0	
5	30	+40	60		1.5	
7	45		80		3.6	
6	50	+60	60		2.1	

Maximum for Z. D. 60° is 3.9 mm.
80 5.7

Table B shows for various extreme positions of the tube the apparent distance in mm (estimated in terms of the radius of m) between C and the coincident R and m.

Here it is seen that the maximum flexure (if this be the cause) occurs when the telescope is in the meridian. This seems plausible from the fact that on the side towards the pier the arrangement for slow motion in declination affords an extra support to the tube extending for more than a third of its length.

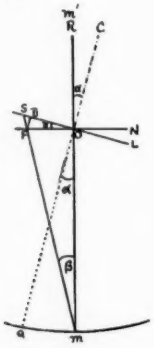


FIG. 8

From the relations of Fig. 8 may be deduced the error in position of a star S at a given angular distance β from the optical axis, on a plate SL inclined a given angle α to the normal to the axis PN. PD is drawn $\perp$ to SL; SD is the distance required.

$$\tan \alpha = \frac{QM}{OM} \quad (1)$$ where QM = the observed displacement in mm.
OM = the focal length of M.

In the $\triangle$ OPD, for the small angle α

$$\tan \alpha = \sin \alpha = \frac{DP}{OP}$$

Whence

$$DP = OP \tan \alpha \quad (2)$$

But

$$OP = Om \tan \beta \quad (3)$$

Substituting in (2) values of OP and tan α from (1) and (3)

$$DP = Qm \tan \beta \quad (4)$$

In the $\triangle$ SDP

$$SD = DP \tan SPD = DP \tan (\alpha + \beta) \quad (5)$$

since

$\angle$ mPO $= 90° - \beta$
$\angle$ OPD $= 90° - \alpha$
$\angle$ SPm $= 180° =$ mPO $+$ OPD $+$ SPD $= 90° - \beta + 90° - \alpha +$ SPD

therefore

$$SPD = \alpha + \beta$$

Substituting in (5) value of DP from (4)

$$SD = Qm \tan \beta \tan (\alpha + \beta) \qquad (6)$$

The quantity SD which comes out in millimeters may be reduced to arc by the use of the factor 87″.4 (for this telescope).

Table C shows the maximum error in position which may be expected for stars at three different distances (ρ) from the axis, on plates taken at extreme zenith distances.

TABLE C.

Z.D. \ ρ	10′	20′	30′
°	″	″	″
60	0.004	0.015	0.031
80	0.008	0.024	0.048

SUMMARY.

The collimation of the 24-inch reflecting telescope of the Yerkes Observatory is made comparatively simple by the use of an 18 mm collimating telescope carrying cross-wires in the eye-piece and over the objective, in connection with a tiny paper disk marking the center of the large mirror.

The object of the process is to find where the optical axis strikes the photographic plate and to make the plate normal to the axis. This is accomplished by making coincident three points: 1) the center of the large mirror, 2) the center of the objective of the collimating telescope, and 3) the reflection of the latter point from the large mirror.

These three points having been made coincident when the telescope points to the zenith, a determination is made of the scale-readings of the plate-carrier when the axis of the large mirror strikes the center of the plate, for various positions of the telescope. The maximum error remaining, due to tilt of the plane of the plate, is calculated from the displacement from 2) of the coincident 1) and 3) above, for extreme positions of the telescope. The investigation shows that for zenith-distances less than 60° and for stars within half a degree of the axis the error in position of the image on the plate must fall below 0″.03.

Yerkes Observatory, April 1920.

SOME RESULTS OBTAINED WITH THE SELENIUM CELL.

By LEWIS J. BOSS.

The selenium cell, properly made, is one of the most delicate light sensitive devices we have today. Metallic selenium conducts electricity and exposure to light increases its conducting power. The peculiar effect to light is best exhibited on selenium which has been exposed for a considerable time to a temperature of 210 degrees, until it has attained a granular crystalline structure. In preparing these cells certain import-

ant conditions must not be overlooked, if the completed cell is to be at all satisfactory in the work for which it is designed.

The first condition is, of course, the purity of the selenium used. Impure selenium crystallizes less completely in a given time than pure selenium. Porcelain, glass, and mica are all good supporting materials, but the latter is preferable since it is less affected by high temperatures and sudden cooling. Platinum wire is ideal for electrodes but since it is scarce and high in price the tendency will be to use copper. The only drawback to copper wire lies in the fact that at the temperature required for annealing, a thin film of copper selenide forms which covers the wire. This also materially increases the resistance of the cell.

In the past the application of selenium cells has been sporadic and even its present status remains more or less in an experimental stage. Among other applications we find that Minchin used it in his astronomical work and that Prof. Joel Stebbins of the University of Illinois has used selenium cells in variable star work. Much room for improvement still exists, however. But before we can apply the cells to any purpose we must know more about them than the bare fact that light causes them to lower their electrical resistance. In the first place the color of light appears to affect them to a certain degree. Below is a table showing galvanometer deflections with the cell exposed to different portions of the spectrum:

Kind of Light.	Points Deflected.	Impressed E.M.F.
White. (Tungsten filament)	5.00	3 volts.
Blue. (Cobalt glass)	3.15	3 "
Red. (Very dark, non-actinic)	2.20	3 "
Amber.	2.85	3 "
Ray filter. (Photographic)	3.00	3 "
Blue and Ray filter.	2.00	3 "
Red and Ray filter.	1.80	3 "
Amber and Ray filter.	1.75	3 "
Red and Amber.	1.50	3 "
Blue and Amber.	1.95	3 "

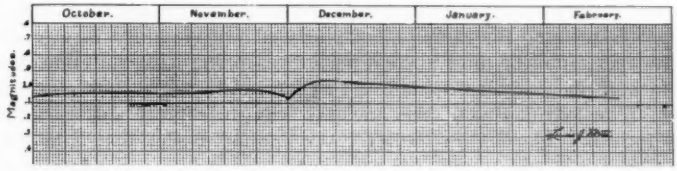
From the above it is seen that the light from a small tungsten flash light bulb produces the greatest deflection. The succeeding values seem to indicate that the blue and ultra-violet end of the spectrum produce a more marked effect than does the red end. In support of this, less deflection was obtained with filters which cut out the violet end of the spectrum than with those which cut out the red end. From this fact we may infer that the thermo-electric effects within the cell itself are very small, much smaller than was once supposed.

In applying the cell to astronomical uses such as detecting variability, it would seem as though due care ought to be taken in compensating for color of light, as well as for clearness of seeing. It would perhaps be well to examine the spectrum of the star to be observed, before hand, and bearing in mind the characteristics thus revealed, proceed to apply the selenium cell accordingly. Thus stars of a reddish hue would give smaller deflections than those of a blue tint or white.

The rapidity of the change in conductivity is very great, in all cases taking place in less than .01 second. This is such a negligible quantity

that it may be ignored for our purposes. When a cell has been exposed for a long time to a strong light a phenomenon occurs which is known as fatigue. That is, the cell becomes insensitive to further changes in light intensity. When not in use the cell should be kept in the dark and it will retain its sensitiveness longer if exposed to light every day or so. I have noted that after some time the dark resistance of the cell decreases, and in an endeavor to find some way of bringing back the original sensitivity of the cell I found that by subjecting the cell to a small low potential alternating current the resistance may be restored to its normal value. There does not seem to be any way in which a cell injured by over exposure to light can be restored to normal conditions fully.

As Marc has calculated the thickness of the selenium layer which is affected by the light action to be about 1/1,500,000 inch thick, it can be seen that the thinner the sheet of metallic selenium used in the cell the more sensitive it will be. This is due to the fact that the proportionate decrease in resistance will be greater for a thin layer of selenium than for a thick one. Consequently a cell utilizing a very thin layer in its construction will be more sensitive to small variations in light intensity and so become more suitable for astronomical purposes. The spacing of the grid wires is immaterial except in so far as the resistance of the cell is increased as a whole. For variable star work a cell with grid wires spaced very close gives the best results.



LIGHT CURVE OF α ORIONIS.

I am reproducing herewith a curve of the variable star α Orionis, made last winter with a cell having the following characteristics: Area exposed 3-8 inch, resistance in dark 1,500,000 ohms, in light 333,330 ohms, grid wires spaced rather far apart, about 1/32 inch. The voltage used was three volts and was maintained at this pressure constantly by means of a rheostat.

The observations were begun in the first week in October and continued on every favorable night up to the second week in February. As seen from the curve during October there was only a very slight variation and the first three weeks in November did not exhibit much fluctuation. During the latter part of the month, however, a marked decrease in brilliance was noted and by December 1 it was less brilliant than at any time since it had risen in the early part of September. A most abrupt increase in luminescence now took place and the first week in December saw the star higher than ever. On December 20 it was one-tenth brighter than Rigel. From this point it seemed gradual-

ly to decrease in brightness until I ceased to take observations in February. This decrease was most gradual, however. This year I shall be in a position to observe more and I shall begin observations sooner than last year in the hope of determining some period of variability.

From the foregoing it can be seen that much yet remains to be done if the selenium cell is to attain its merited place in the astronomical field, for which it seems admirably suited. The amateur as well as the experienced astronomer can help and in fact it is to the young experimenter as well as to the advanced physicist that we must look for new developments along a new and untried path.

September 12, 1920.

LEGENDS OF THE CREATION.

By RUFUS O. SUTER, JR.

The religions of bygone ages have bestowed upon us a vast number of supposedly inspired accounts revealing the manner of the creation of the Universe. The Mosaic narrative is not the only one to have received credulance. Other races held their own opinions. It will be interesting to read some of these. Historically the tales possess a limited degree of value. They indicate the poetic, imaginative ingenuity characterizing the early philosophers who propounded them. They prove that from the most ancient period reasoning man has endeavored to fathom the enigmas of nature. Scientifically the accounts are useless. The astronomy of the ancients was little more than primitive superstition and religious belief. We cannot expect that they could have known in what manner the Universe was created when present day astronomers with all their data both mathematical and observational are unable to solve the problem. There are many adherents of each religion, however, who solemnly declare the author of their account wrote under Divine influence. Is it not just as illogical to hold such a belief as this as it is to overly criticize the legends? Let them be valued at what they are—man's earliest attempts to explain natural phenomena.

The Ancient Greeks and Romans perfected a scheme of creation which in many respects is the most logical of them all. They believed Earth is the center of the Universe—an error on the start; but let us remember such a theory has received almost unanimous credulity since primitive man first stepped out of his cave blessed with the faculty of reason, until the publication of Copernicus' epoch-making book in 1546. The Greeks and Romans believed Earth was created first—but not out of nothingness. There had always existed a state called Chaos which contained the fundamental principles of all things destined to be.

This Chaos had been the scene of most violent struggling between the opposing elements of nature. There were no gods to rule it; the elements clashed without regard to law and order; they existed in a perfect anarchical state. Gradually, however, a dominating power arose, named by the philosophers, Eros—Love. Through his management all the contending forces were separated and the kindred ones united. Then Earth came into existence as a natural result of the transformation, followed shortly afterwards by the heavenly bodies. The ancients realized that for such a complete metamorphosis an immense period of time was required. They were not sparing in providing this, for they taught that three great dynasties of gods had ruled successively since the beginning of the change until their time. Zeus headed the last and most perfect of these dynasties.

The Egyptians propounded a theory which in one respect resembles that of the Greeks and Romans. They believed that such a state as nothingness is impossible. Infinite space had always been occupied by infinite ocean before the heavenly bodies and Earth came into existence. In another respect, however, they differed with their contemporaries. As they were sun-worshipers they believed that that body was created first. He was hatched from an egg floating on the boundless sea. Their explanation of Earth's existence is singularly magnificent. Certain gods caused it by separating the finite, our planet, from the infinite, thus creating both Earth and heaven at one stroke.

No legend is more characteristic of its propounders than that of the Japanese. In the beginning there was nothing save boundless space, a number of superior deities, and the Lord of the Middle Heavens. By the supernatural influence of these Creators an immense, nebulous mass was brought into existence, and this gave birth to a flowering rush-sprout which gradually increased in size until it covered all things becoming the celestial dome. The lower regions of the cloud-like mass were transformed into realms of gloom inhabited only by condemned souls and departed spirits awaiting judgment, and the remaining portion, though no more than a lifeless, liquid mass, was destined to become the home of man. The Japanese, like the Greek and Roman philosophers, realized how long a period of time was required for such radical changes, consequently they allowed for the passing of seven generations of gods before Izanagi and Izanami, the parents of Earth, began their work. "Get ye down onto yonder sea," the superior gods commanded them, "and make it a luxuriant world." Straightway Izanagi and Izanami, who were god and goddess, descended near future Earth by means of a flowery bridge, and commenced to stir its green waters with a spear which the higher deities had given them. This motion resulted in axial rotation. When the parents of our world raised their weapon from the water, brine was raised also and became Japan. Izanagi and Izanami now stepped onto the new land. They were affected by the desolation surrounding them and wandered aimlessly about. At this moment however an epoch-making event

occurred. Two little birds--whose origin is unexplained—alighted and entertained each other with such beautiful tales of love that even the everwatchful superior gods were greatly impressed and struck love into the hearts of Earth's parents. They wedded and we terrestrials are their descendants . . . . One day Izanagi bathed his left eye and to his utter amazement a beautiful woman leaped out. "O, prodigy," he exclaimed tossing her up into the celestial dome, "thou shalt rule the day, bestowing light and warmth upon the sons and daughters of men." He washed his right eye. A handsome youth sprang forth. "Thou I will hurl into the night sky," he cried, "to give light unto belated travelers and receive their blessings." This tale leaves a tendency for laughter—but as a matter of fact it possesses an explanation of one phenomenon which the thoughtful Greek and Roman philosophers did not even know existed—Earth's axial rotation.

We will now investigate a most popular subject—the Jewish or Mosaic account, delicate to handle because both the Christian and Mohammedan Churches have accepted it as an inspired piece of writing. This fact, however, will not influence our discussion, for, judging from the account itself, there is no reason to believe it any more inspired than the traditions of other nations. As a classic myth the tale certainly stands first because it deals freely in the fantastic and supernatural, and is unexcelled in its magnificence of style. God, as he is portrayed in other primitive literature, is the counterpart of man, "writ large" to be sure, but still a possessor of human attributes and sensations. He created the Universe out of nothing in six days and rested on the seventh because he was exhausted. Is this not a typical Eastern legend? Some prefer to believe that each of these days represents a thousand years. It makes no difference. Six thousand years is no more adequate to build a Universe than six days. Both the Greek and Roman philosophers and the Japanese realized an immense period of time was required. During the first day (or thousand years) God created Earth—a body covered with water, but "darkness was upon the face of the deep." Hence he made light as though it were a self-sustaining element not emitted or reflected from material objects. On the second day the firmament was brought into existence; on the third day land appeared and vegetation began to grow though the sun had not yet been created. Now as late as the fourth day sun, moon and stars, appeared solely for the pleasure and convenience of man. During the fifth day sea and flying life came into existence, and on the sixth animals and man appeared. The Hebrew account is subject to the same errors all others are—Earth was made first and is the center of the Universe. You may judge for yourself—is this an inspired writing, absolutely correct, or the characteristic legend of a primitive race?

We soon, however, will appreciate the Mosaic account regardless of its fallacies. Witness the Norse legend. Odin, Vile and Ve slew an immense giant called Ymir, and having rounded his corpse, hurled it

into Guningagap, the yawning abyss between Niflheim and Muspelheim. Thus Earth was formed; his projecting bones making mountains; his flesh, dry land; his hair, forests; his teeth, mixed with particles of bone, rocks and pebbles; blood gushing from a wound in his side, the ocean; his skull the concave heavens; his brains the clouds. The sun, moon and stars are sparks of fire from Muspelheim, each following a permanent course in our skull-structured heavens placed there to give light on Earth and to guide the vikings. One may ask, "What made Ymir?" The Norsemen answer, "hoarfrost."

Query: What sustained him? Answer: The milk of a cow.

Query: What made the cow? Answer: Hoarfrost.

Query: What sustained her? Answer: Salt.

Query: What made the salt? Answer: Frozen glaziers from Niflheim.

Query: What made the hoarfrost? Answer: Vapor from Niflheim uniting with heat from Muspelheim.

Query: What made Niflheim and Muspelheim?

Here the Norse legend may seem to halt; but no—those persevering vikings were not to be baffled so easily. Though seldom occupied with philosophic meditation, they firmly believed in an original state of nothingness out of which, at the command of a far mightier god than Odin, Niflheim and Muspelheim had sprung. This supreme deity never considered such things as restricted time and the finite—his thoughts soared to eternity and the infinite. The Norse legend, the extremely primitive, contains the germ of one great truth—the sphericity of Earth. Moreover these vikings realized the very thing in which the thoughtful Hebrew philosopher erred—vegetation could not and did not grow until Old Sol began to shine in the heavens.

TWENTY-FIFTH MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY.

ABSTRACTS AND PAPERS.

(Continued from page 160.)

THE ORBIT OF THE SPECTROSCOPIC BINARY BOSS 5070.

By W. E. Harper.

This star ($\alpha\ 1900 = 19^h\ 47^m.2$, $\delta\ 1900 = +\ 40°\ 20'$, visual magnitude 5.62, type B3) was anounced a spectroscopic binary by Adams from three plates taken in 1912. A few observations were made by the writer in 1915 and 1917 at Ottawa which suggested the period, and the past summer sufficient observations were obtained here at Victoria to determine the elements of the orbit.

The Ottawa observations indicated that the calcium K line did not share in the large oscillations of the other lines and care was taken

to have the Victoria plates well exposed in that region. On nineteen plates it shows as a fairly sharp line giving a constant velocity —17.4 ± 1.0 km/sec., a velocity which is 11 km more negative than that of the system as a whole, and which if corrected for the sun's motion through space would be approximately zero.

Besides the usual hydrogen and helium series whose lines, though 3 or 4 angstroms in width, are fairly well measurable there are faint silicon lines at λ4567 and λ4552, a faint magnesium at λ4481 and occasionally the carbon at λ4267. In general from five to eleven lines were measured on each plate.

The period was deduced from connecting up the observations of the four different years 1912, 1915, 1917, and 1920, and gave a value 12.427 days. This element was considered sufficiently well determined and did not enter into the least-squares solution which was effected for the remaining elements and which gave final values as follows, the probable error of a plate being ± 3.0 km/sec.

$$
\begin{aligned}
P &= 12.427 \text{ days} \\
e &= 0.199 \pm .021 \\
\omega &= 120^{\circ}08 \pm 1^{\circ}29 \\
\gamma &= -6.18 \text{ km} \pm 1.79 \text{ km} \\
K &= 94.40 \text{ km} \pm 2.14 \text{ km} \\
T &= \text{J. D. } 2419636.226 \pm .076 \text{ day} \\
a \sin i &= 15{,}808{,}000 \text{ km}
\end{aligned}
$$

$$
\frac{m_1^3 \sin^3 i}{(m + m_1)^2} = 1.02 \odot
$$

THE NORTH AMERICA NEBULA.

By F. Henroteau.

A photograph was shown, taken on a Seed 30 plate with a lens 2 inches in diameter and 12 inches focal length (1920 October 10, 3 hours exposure). This photograph exhibits a very large nebula, extension of the North America Nebula, already known. The new nebula covers an area of 10.5 square degrees, while the North America Nebula only covers 1.6 square degrees.

The great transparency of the sky at the time of the exposure and perhaps a greater sensitiveness of the plate for light of favorable regions of the spectrum, are responsible for the detection of the larger nebula.

THE PHOTOGRAPHIC LIGHT-CURVE OF NOVA CYGNI NO. 3.

By F. Henroteau.

The light-curve of Nova Cygni No. 3 was obtained from photographs taken at the Dominion Observatory, by the author, as well as by J. P. Henderson, R. M. Stewart, and E. C. Arbogast. The photo-

graphs were taken with a small wide-angle camera covering a field of the sky of about 20 degrees in diameter. The method of degrees was used to obtain the magnitudes. Two series of plates were secured; the first on Seed 30 plates, and the second on Cramer Isochromatic plates. The latter series gives magnitudes which are more similar to visual estimates.

The observations extend from August 24 to October 12. Compared with the visual observations compiled by C. Luplau-Janssen and Georg E. Haarh, the above photographic light-curve indicates that the color of the Nova changed gradually from blue to yellow, and perhaps to red. The curve will be published in the *Astronomical Journal*.

RECENT PHOTOGRAPHIC OBSERVATIONS OF SEVERAL WELL-KNOWN NOVAE.

By C. O. Lampland.

Observations of novae in their fainter stages have for some years been a part of the program of the 40-inch Lowell reflector. The paper contained a short account of the photographic observations of Nova (Q) Cygni (1876), Nova (T) Aurigae (1891), Nova Persei (1901), Nova Geminorum 1 (1903), Nova Lacertae (1910), Nova Geminorum 2 (1912), and Nova Monocerotis (1918). Magnitude observations were given for all of these stars and preliminary measures for proper motion for all but the last one.

Magnitudes. The last observations referred to are in all cases November and December 1920. The magnitudes are photographic. Nova (Q) Cygni: Only small variations in light noted on the photographs, present magnitude about 15. Nova (T) Aurigae: Light nearly constant in recent years, magnitude now approximately 14.7. Nova Persei (1901): A slide was shown of the plotted light values for 125 dates, from February 8, 1917 to December 4, 1920. The Nova has undergone marked fluctuations in brightness in this interval, the observed range being about two magnitudes (13-15 approximately). The wisp of nebulosity near the Nova, discovered by Professor Barnard in 1916, has been photographed frequently. The nebulosity is moving away from the star (0″.25, or a little more, per year), its form has changed slightly and there is an appreciable increase in its width. Nova Geminorum 1: The star is gradually and slowly falling off in light, and it is now fainter than magnitude 16. Nova Lacertae: The light of this star has apparently been quite constant in recent years, the magnitude is now about 14.5. Nova Geminorum 2: Small fluctuations have been noted in this star but the light is gradually becoming fainter, the magnitude at present is about 13.5. Nova Monocerotis: In March 1918 it was near magnitude 10, in November 1920 it was a little fainter than magnitude 15.

Proper Motion. The observed components of proper motion of these novae, relative to the faint comparison stars used, are in all cases

very small. It is to be expected that these preliminary values may be considerably altered by additional observational material. A more detailed account of these observations will appear in the *Lowell Observatory Bulletin*.

Nova	μ_x	μ_y
	"	"
Q Cygni	+0.004 ± 0.003	+0.003 ± 0.002
T Aurigae	−0.002 ± 0.004	−0.003 ± 0.004
Persei (1901)	−0.009 ± 0.003	−0.015 ± 0.003
Geminorum 1	(−0.007)	(−0.003)
Lacertae	+0.000 ± 0.005	+0.001 ± 0.008
Geminorum 2	−0.014 ± 0.004	+0.017 ± 0.004

μ_x and μ_y are the observed components of proper motion, reckoned positive in the sense of increasing Right Ascension and Declination.

The observations for the earlier epochs are Professor Barnard's micrometric measures, except in the case of Nova Geminorum 2. The values for this star are based wholly on the 40-inch photographs.

The first results for Nova Persei (1901) were obtained early in 1917, but with little confidence that the values had any further significance than to show that the motion was small. These first results, however, may be said to be in good agreement with the present values based upon a much larger amount of observational material both for the earlier and later epochs.

PROGRESS IN OBTAINING PARALLAXES AND PROPER MOTIONS IN THE TWENTY-FOUR AREAS SELECTED BY KAPTEYN IN 45° OF NORTH DECLINATION.

By Oliver J. Lee.

Over ninety per cent of the necessary plates have been taken. About fifty per cent of the measurements and reductions have been made. An attempt is made to get everything possible out of the plates taken with the 40-inch telescope, viz., proper motion in both x and y, and the parallax of every measurable star in the field. The former are based upon four exposures, two at each extreme epoch. The latter is derived from eight or more exposures.

THE EXCEPTIONALLY HIGH SOLAR PROMINENCE OF OCTOBER 8, 1920.

By Oliver J. Lee.

This paper presented some of the results gotten from a study of the fifty-seven photographs obtained of this eruption. The crest attained the highest altitude so far recorded, 531,000 km, or more than 19′. Photographs were exhibited showing the early stages in the development of the structure, in particular how the various degrees of separation of the head from the base took place. The highest velocity

observed was 155 km/sec. Several cases of peculiar motion were studied. The separation of the head into parts which continued the upward course unchecked and other parts which reversed their motion and fell back upon the sun is especially noted.

ON THE AGE OF THE STARS.

By F. R. Moulton.

Attempt was made to get some idea of the duration of the stars from dynamic consideration of the globular clusters. Their symmetrical distribution, which in many cases follows approximately the same law, implies that they have arrived approximately at a steady state through a long dynamic evolution. It is reasonable to suppose that this evolution has taken place during the life of the stars of which the clusters are composed.

The period required for a single circuit of a star through a globular cluster is of the order of a million years. The dynamic evolution results primarily from the occasional near approaches of stars. It is found that on the average a star would make several thousand revolutions before it would pass near enough some other star to change its direction of motion from that which it would otherwise have by so much as ten degrees. Consequently it is inferred that the arrangement of the stars in globular clusters points to the conclusion that the stars of which they are composed are several thousand million years of age.

THE DRAKE UNIVERSITY MUNICIPAL OBSERVATORY.

By D. W. Morehouse.

The city of Des Moines through its City Council voted bonds and appropriated a site in one of its city parks for the erection of a Municipal Observatory. Drake University agreed to equip the building with an 8¼-inch equatorial telescope and all other astronomical apparatus in its possession, and to take charge of and man the building.

The observatory is situated on one of the highest points in the city in the center of a ninety-acre park which is kept as a golf course. The building is of Bedford stone and contains a library and assembly room seating about 150 people, a transit room and an office. The telescope is mounted on reinforced concrete cross-beams supported by the walls of the tower, thus leaving in the center of the building a rotunda below the telescope room. In the floor of the rotunda the design of the solar system is depicted in mosaic. The telescope room is reached by a circular stairway through a separate passage from which entrance to the observatory is made on the floor level. A balcony extends around the entire dome and communicates with the roof of the auditorium, thus giving a spacious promenade for naked eye observations. A small

balcony lined with ground glass for the display of astronomical transparencies encircles the inner wall of the auditorium.

The entrance to the building is quite artistic. A large sun-dial stands just in front of the main entrance. In raised panels on either side of the door the zodiacal signs are carved. Above the door is the conventional sign of the sun, on either side of which are the dates J. E. 6633 and A. D. 1920. It is planned to make the building as attractive and dignified as possible in order to put before the public the beauty and dignity of the study of astronomy.

The observatory is to be open to the public at stated frequent intervals, at least two evenings per week and one afternoon. The coöperation between the University and the city is very cordial and no pains or trouble is being spared in making this one of the attractive features of the city. The newspapers have been remarkably cordial and helpful in the project and the greatest interest is manifested by the people.

THE SHORT-PERIOD SPECTROSCOPIC BINARY 65 τ CYGNI.

By J. S. Paraskévopoulos.

τ Cygni is a well-known visual binary with a period of about forty-seven years. In 1908 S. B. Barrett announced that the bright component is a spectroscopic binary, but the period had not been determined until a continuous series of plates obtained by the author at the Yerkes Observatory on the night of July 16, 1920, showed that the period is only $3^h\ 25^m$, the shortest known at this time. The eccentricity is 0.3 and $a \sin i$ only 14,900 km. By assuming the surface brightness to be the same as the sun's, since there is little difference in spectral type, the radius of the principal component is found to be larger than the distance between the two components of the spectroscopic binary. Neither the hypothesis of a pear-shaped body nor an explanation along the line of the pulsation theory seems acceptable.

OBJECTIVE-PRISM SPECTRA OF NOVA AQUILAE 3 AND NOVA CYGNI 3.

By J. A. Parkhurst and E. B. Frost.

These spectra were taken with prisms of 15° and 30° angles, with apertures of 15 cm, used in connection with a Zeiss UV camera of 84 cm focal length and a Brashear reflector of 150 cm focal length; occasionally over the two-foot reflector of the Yerkes Observatory. Most of the plates used were red-sensitive.

The progressive changes from absorption to emission spectra, followed by a change to the nebular stage, was shown by nineteen spectra of Nova Aquilae, between 1918 June 8 and August 26, and thirty-four spectra of Nova Cygni taken between 1920 August 23 and December 8.

In case of each star, the spectrum was in the absorption stage the first two nights, changing to pronounced emission on the third night. In case of Nova Cygni, the first and second nebular lines appeared between October 16 and 21, and gradually increased in strength till the end of the series.

After the appearance of the emission lines, the α line of hydrogen retained its relative strength throughout the series, the β line showed a marked decrease and the γ line a slight increase in strength.

Another pronounced change can be seen in the λ4600 region. On the earlier plates the strong absorption line λ4590 is flanked by continuous spectra or emission of equal strength on each side. The emission on the red side greatly increased as compared with that on the violet side, until on the later plates it was only visible on the red side of the λ4590.

Pairs of spectra show close resemblance between the two novae, if allowance is made for difference in brightness.

THE DIAMETER OF α ORIONIS BY MICHELSON'S INTERFEROMETER METHODS.

By F. G. Pease.

In 1890 Michelson pointed out the possibility of measuring by interference methods, the diameter of planetoids and satellites and the distance between double stars, and also showed how the method might be used in determining the diameter of a star.

He measured the diameters of Jupiter's satellites with the 12-inch Lick refractor in 1891, and in August 1919 obtained interference fringes with the 40-inch refractor of the Yerkes Observatory, and with the 100-inch reflector at Mount Wilson in September of the same year. In December 1919 and the months following, Anderson obtained measures of the distance and position angles of the components of Capella with great accuracy. At Professor Michelson's suggestion, an interferometer beam 20 feet long, provided with movable auxiliary mirrors, was then constructed to test conditions of interference at distances greater than the diameter of the one hundred-inch mirror itself. In August 1920 fringes were obtained with separations of the mirrors as great as 18 feet, the visibility of the fringes for Vega at this distance being as great as that at 6 feet.

Meanwhile, Eddington, Russell and Shapley had obtained values for the diameter of a number of stars based on estimates of apparent surface brightness, and their results indicated that several of these lay within the range of the 20-foot beam. α Orionis in particular was so large that Merrill investigated it with the apparatus used in the measurement of Capella and found a definite decrease in visibility for the

maximum separation of the slits, (100-inch aperture), this holding true for all position angles.

On December 13, 1920, with the outer mirrors of the 20-foot beam at 121 inches separation, no fringes were visible on α Orionis, while observations on γ Orionis before, and on α Canis Minoris afterwards yielded strong fringes with practically no change of setting. All measures were checked by Dr. Anderson. The seeing was very good on this night, but poor on the following nights, and it appears that better conditions are required than when working with fringes produced by apertures placed directly before the telescope. Nevertheless, observations made December 14-17 indicate that α Ceti, α Tauri and β Geminorum will come within the range of the 20-foot beam.

Assuming that the effective wave-length for α Orionis is $\lambda 5750$ its angular diameter from the formula $a = 1.22\,\lambda/d$ proves to be $0''.047$, and with Schlesinger's parallax of $0''.016$ its linear diameter turns out to be 271,000,000 miles or slightly less than that of the orbit of Mars.

The uncertainty of the present measurement is about 10 per cent. The effect of a possible darkening at the limb, which has been disregarded, would tend to make the measured results too small.

THE INTENSITY DISTRIBUTION IN TYPICAL STELLAR SPECTRA.

By H. H. Plaskett.

In an earlier paper (*Monthly Notices*, **80**, 771, 1920), an account was given of Merton and Nicholson's method of measuring spectral intensities, applied to the continuous spectrum of γ Cassiopeiae. The essential features in that method are the use of a neutral tint wedge in front of the spectroscope slit, the calibration of the photographic plate by the spectrum of the positive crater of the carbon arc, and the measurement of the resulting spectra by process screen enlargements to eliminate personal errors. This paper contains a further application of this method to some typical stellar spectra. Three features of the work may be noted in this abstract: (1) A simplification in the theory, (2) improvements in the method of securing and measuring spectra, and (3) some preliminary results.

(1) The result of the simplification in theory has been to show that the fundamental assumption in the method is the following. On a given plate for a given time a monochromatic source of constant intensity will always produce the same blackening. None of the various photographic effects such as the failure of the reciprocity law, or the variation of density, contrast and inertia with λ vitiate this assumption. Practically it is true within a few per cent, the variations being due to secondary and local effects which enter as accidental errors into the final result.

(2) The method, as applied to γ Cassiopeiae, was not practical on account of the excessive exposure times required (two hours for a sec-

ond magnitude star); and also because of the time and labor involved in the measurement of the spectra once secured. These two difficulties have been largely overcome. A less dense wedge secured in July from Hilger's reduced the exposure by about seventeen times. It disclosed, however, a peculiar effect, due either to the driving clock or to irregularities in atmospheric refraction, which made it impossible to secure uniformity of illumination by trailing the star along the length of the wedge. After a number of tests it was found possible to secure this uniformity of illumination, which is essential, by trailing a star image elongated along the slit by a cylindrical lens.

In the measurement of the spectra, the quantity desired is the height of the spectrum measured up to a certain constant density at various wave-lengths. It has been found possible to measure these heights by means of a microphotometer, constructed from the well-known Hartmann spectro-comparator by the addition of one or two accessories. The new method has resulted, not only in an increase of the ease and speed with which the plates are measured, but also in a gain in accuracy.

(3) Using this modified method a number of spectra have been secured of eight bright typical stars. The plates have been measured, and the intensity distributions in the continuous spectra have been computed. A preliminary discussion of these results indicates two things of interest. (*a*) There is observed, particularly in the sun, a marked drop in intensity between 0.50 μ and 0.67 μ which is not obtained by Abbot. It seems reasonable to conclude that this is an error, due either to an emission band in the carbon arc spectrum, or possibly to a marked atmospheric water vapour absorption (the solar zenith distance was 70°). These two possibilities are at present under invesigation. (*b*) The other feature of interest has to do with the early type stars. In confirmation of the earlier work with γ Cassiopeiae (B0p), it appears that the intensity rises too steeply in the blue and violet to conform to black body radiation. As a working hypothesis it may be assumed that, superposed on the thermal radiation, is a continuous spectrum due to hydrogen, helium and other gases, such as has recently been discussed by E. P. Lewis (*Physical Review*, **16**, 367, 120).

This paper in a final complete form will appear in the *Publications of the Dominion Astrophysical Observatory*.

THE SPECTROSCOPIC ORBIT OF Z VULPECULAE.

By J. S. Plaskett.

The spectroscopic orbit of Z Vulpeculae, R. A. $19^h\ 17.5^m$, Dec. +25° 23′, magnitude 7.1, spectral type B3, has been determined from eighteen spectra obtained between April 22 and November 7, 1920.

Although from Shapley's photometric orbit the brighter star gives three-fourths of the light of the system, the spectrum of the fainter

component has been measured on twelve of the spectra obtained giving results in fair interagreement and there can be no doubt of the reality of its presence. Both spectra are diffuse, with lines lacking in contrast and difficult to accurately measure, the probable error of measurement of a single plate being ± 6.0 km/sec. for the bright and ± 10.1 km/sec. for the faint component. Although the photometric orbit indicates the presence of a small eccentricity $e \cos \omega = 0.013$, the spectroscopic observations are not of sufficient precision to determine the amount and only suffice to show it must be very small, probably not over 0.02.

The elements of the assumed circular orbit were corrected by least-squares and gave the following values

Semi-amplitude brighter star	$K_b =$ 96.3 km	± 1.1 km
Semi-amplitude fainter star	$K_f =$ 213.7 km	± 5.6 km
Velocity of system	$\gamma =$ —15.1 km	± 1.1 km
Time of spectroscopic phase	$T =$ — 0.014 day	± 0.008 day

Combining Shapley's photometric orbits with the above we obtain

		Uniform	Darkened
Separation of two stars	$a =$	15.06 ⊙	15.05 ⊙
Radius bright star	$r_b =$	3.78	4.23
Radius faint star	$r_f =$	4.73	4.46
Mass bright star	$m_b =$	5.25	5.24
Mass faint star	$m_f =$	2.37	2.36
Density bright star	$\rho_b =$	0.135	0.085
Density faint star	$\rho_f =$	0.031	0.033

If we assume the surface intensity of a B3 star as compared with the sun is —2.7 magnitudes the absolute magnitude of the brighter component of Z Vulpeculae is —0.9 and its parallax is 0".0022.

THE MUTUAL ACTION OF ADJACENT PHOTOGRAPHIC IMAGES.

By Frank E. Ross.

A review of the work of Kostinsky, Lau, Turner, Bellamy and others on the attraction and repulsion of neighboring star images was given. The factors which control the action were shown to be (1) *turbidity*, causing an attraction through optical reinforcement of the images on their adjacent sides. A formula was derived giving the amount of this attraction. (2) *Gelatine* disturbance, causing an attraction also. (3) *Developer* action, in which development of the images on their adjacent sides is retarded, owing to the products of reaction, as in the Eberhart effect. This leads to a repulsion. In the case of neighboring absorption spectral lines there is an additional effect due to a difference in sharpness of the edges which is caused by turbidity and halation.

Experimental data on the behavior of artificial double stars, close bright lines, and close absorption lines were described. It was shown that in experiments of this nature important differences develop depending on whether the exposures are normal or overexposed. The

contradictory results obtained by various investigators is thus explained. If the behavior is investigated by means of overexposure, strong repulsions of neighboring images are found except in the case of absorption lines in which a strong attraction is found. In the case of normal exposures, which is of most interest in general, an attraction is usually obtained amounting to two or three microns. In order to reduce the effect, which enters as an error of importance in measurements of this kind, *the exposure must be reduced to a minimum.* In the case of overexposures, considerable variation of the repulsive action was obtained by varying the developer. Curves for a number of developers were given in which it is shown that an attraction sets in, followed by a repulsion as the distance becomes less. It is important to make a further study of developers.

A WIDE-ANGLE ASTRONOMICAL DOUBLET.

By Frank E. Ross.

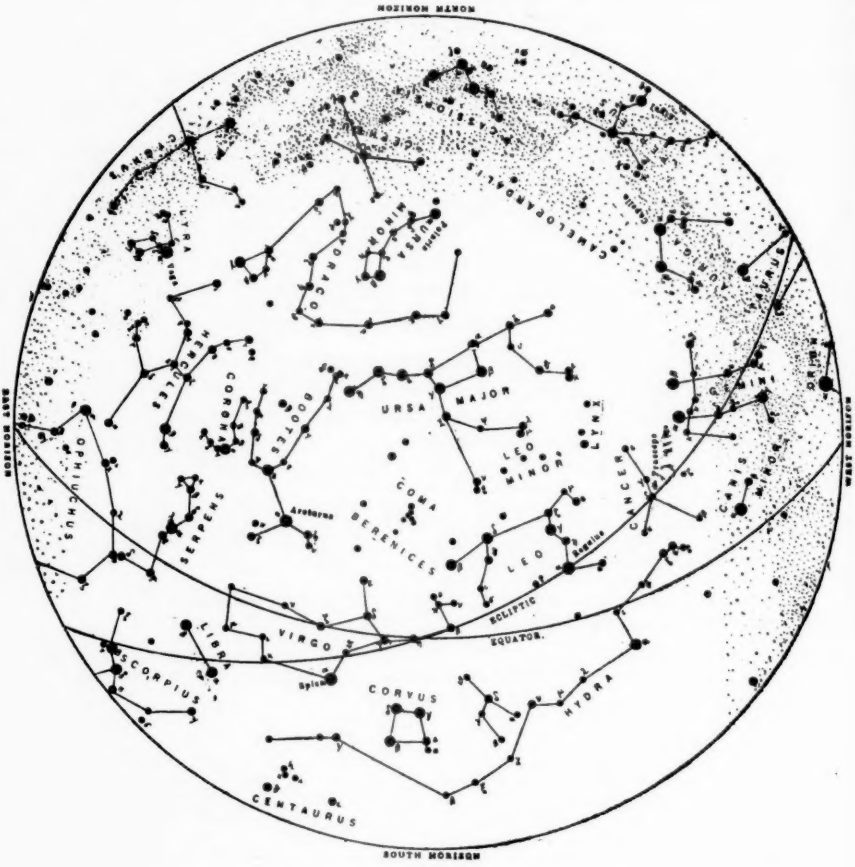
By making use of the field-flattening properties of modern glasses, a lens has been designed, working at the moderate aperture-ratio of one to fourteen, which possesses a total field of critical definition of about 25 degrees. The lens is of the four-piece separated type, the elements being thin and the curves flat. The glass is as follows:

	$\mu_{G'}$	ν
Positive elements A and D	1.61984	58.0
Negative elements B and C	1.56275	45.8

The lens is fully described in the *Journal of the Optical Society of America* for March, 1921.

(To be continued.)

PLANET NOTES FOR MAY.



THE CONSTELLATIONS AT 9:00 P. M. MAY 1.

The phases of the *moon* will be as follows:

New Moon	May 7 at 3: 1.5	P.M.	C.S.T.
First Quarter	14 " 9:24.8	A.M.	"
Full Moon	21 " 2:15.4	P.M.	"
Last Quarter	29 " 3:44.6	P.M.	"

Mercury will be at its ascending node on the 9th, at 10 P. M., and seven hours later superior conjunction will occur. The planet will be in perihelion on the 14th and have its greatest heliocentric latitude north on the 24th.

Venus, having just passed inferior conjunction, will appear in the morning sky before sunrise. On the 5th the planet will be in conjunction with the moon;

on the 11th it will be stationary and will have its greatest brilliancy on the 28th when its stellar magnitude will be —4.2.

Mars will be too near the sun and too far from the earth to be observed readily.

Jupiter and *Saturn* will be near each other in the eastern part of Leo and admirably placed for early evening observations. Jupiter will be at quadrature on the last day of the month. Elsewhere in this issue will be found the phenomena for the satellites of these two planets.

Uranus will be in Aquarius and will reach quadrature on the last day of the month only eight hours before Jupiter takes the same position in the diametrically opposite part of the sky.

Neptune will be in Cancer reaching quadrature on the 1st. Its position will be such that it forms practically an equilateral triangle with ξ and γ Cancri, being south of those stars. It may be of interest to those possessing small telescopes to try to locate the planet.

Occultations Visible at Washington.

[*From the American Ephemeris.*]

Date 1921	Star's Name	Magnitude	IMMERSION. Washington M.T.	IMMERSION. Angle E from N	EMERSION. Washington M.T.	EMERSION. Angle E from N	Duration
			h m	°	h m	°	h m
May 13	κ Cancri	5.1	8 37	100	9 42	304	1 5
21	88 B Scorpii	6.4	8 36	61	9 30	328	0 54

This is the smallest number of occultations listed for any month since May 1913 for which month only one occultation was listed.

Phenomena of Jupiter's Satellites.

VISIBLE AT WASHINGTON.

[From the *American Ephemeris.*]

CENTRAL STANDARD TIME.

1921	d	h	m			d	h	m		
May	3	8	38	II	Tr. I.	May 15	11	34	III	Ec. R.
		10	55	II	Sh. I.	17	6	50	IV	Ec. R.
		11	27	II	Tr. E.	19	8	42	II	Oc. D.
	4	9	54	III	Tr. I.	21	8	15	II	Sh. E.
	5	8	50	II	Ec. R.		10	39	I	Tr. I.
		12	27	I	Tr. I.		11	53	I	Sh. I.
	6	9	33	I	Oc. D.	22	7	13	III	Oc. D.
	7	6	54	I	Tr. I.		7	46	I	Oc. D.
		8	4	I	Sh. I.		10	32	III	Oc. R.
		9	10	I	Tr. E.		11	18	I	Ec. R.
		10	18	I	Sh. E.	23	7	23	I	Tr. E.
	8	6	35	IV	Tr. I.		8	36	I	Sh. E.
		7	28	I	Ec. R.	26	11	15	II	Oc. D.
		7	36	III	Ec. R.	28	8	4	II	Sh. I.
		10	32	IV	Tr. E.		8	20	II	Tr. E.
	10	11	7	II	Tr. I.		10	51	II	Sh. E.
	12	11	25	II	Ec. R.	29	9	40	I	Oc. D.
	13	11	25	I	Oc. D.		11	10	III	Oc. D.
	14	8	46	I	Tr. I.	30	7	2	I	Tr. I.
		9	59	I	Sh. I.		8	17	I	Sh. I.
		11	1	I	Tr. E.		9	17	I	Tr. E.
		12	13	I	Sh. E.		10	31	I	Sh. E.
	15	8	25	III	Ec. D.	31	7	42	I	Ec. R.
		9	23	I	Ec. R.					

NOTE:—I. denotes ingress; E., egress; D., disappearance; R., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

Saturn's Satellites.

Greatest elongations visible in the United States.
[From the *American Ephemeris.*]
CENTRAL STANDARD TIME.

I. Mimas. Period 0d 22h.6.

1921	d	h		d	h		d	h		d	h	
May	1	13.9	W	May 8	15.5	E	May 14	7.3	E	May 22	7.5	W
	2	12.5	W	9	14.2	E	17	14.4	W	26	13.3	E
	3	11.1	W	10	12.8	E	18	13.0	W	27	12.0	E
	4	9.8	W	11	11.4	E	19	11.7	W	28	10.6	E
	5	8.4	W	12	10.0	E	20	10.3	W	29	9.2	E
	6	7.0	W	13	8.6	E	21	8.9	W	30	7.8	E
										31	6.4	E

II. Enceladus. Period 1d 8h.9.

May	1	3.2	E	May 9	8.5	E	May 17	13.8	E	May 25	19.1	E
	2	12.0	E	10	17.4	E	18	22.7	E	27	4.0	E
	3	20.9	E	12	2.2	E	20	7.6	E	28	12.9	E
	5	5.8	E	13	11.1	E	21	16.5	E	29	21.8	E
	6	14.7	E	14	20.0	E	23	1.4	E	31	6.7	E
	7	23.6	E	16	4.9	E	24	10.2	E			

III. Tethys. Period 1d 21h.3.

May	2	3.7	E	May 9	16.9	E	May 17	6.2	E	May 24	19.4	E
	4	1.0	E	11	14.2	E	19	3.5	E	26	16.7	E
	5	22.3	E	13	11.6	E	21	0.8	E	28	14.0	E
	7	19.6	E	15	8.9	E	22	22.1	E	30	11.4	E

IV. Dione. Period 2d 17h.7.

May	2	7.5	E	May 10	12.6	E	May 18	17.6	E	May 26	22.7	E
	5	1.5	E	13	6.2	E	21	11.3	E	29	16.4	E
	7	18.9	E	15	23.9	E	24	5.0	E			

V. Rhea. Period 4d 12h.5.

May	4	11.3	E	May 13	12.1	E	May 22	13.0	E	May 31	13.9	E
	8	23.7	E	18	0.5	E	27	1.4	E			

VI. Titan. Period 15d 23h.3.

May	6	15.4	E	May 14	10.8	W	May 22	14.0	E	May 30	9.5	W

VII. Hyperion. Period 21d 7h.6.

May	2	8.8	E	May 11	18.6	W	May 23	17.8	E			

VIII. Iapetus. Period 79d 22h.1.

May	6	2.6	S	May 26	18.7	E						

IX. Phoebe. Period 523d 15h.6.

	α Ph.—α Sat.		δ Ph.—δ Sat.				α Ph.—α Sat.		δ Ph.—δ Sat.	
	m	s	°	′	″		m	s	°	′	″
May 1	+1	25.1	−10	45		May 17	+1	34.1	−11	28
3	1	26.5	10	53		19	1	34.8	11	30
5	1	27.8	11	0		21	1	35.4	11	32
7	1	29.2	11	6		23	1	36.0	11	33
9	1	30.4	11	12		25	1	36.4	11	33
11	1	31.4	11	17		27	1	36.7	11	33
13	1	32.4	11	21		29	1	37.0	11	32
15	+1	33.3	−11	25		31	+1	37.1	−11	31

NOTE:—E, Eastern Elongation; I, Inferior Conjunction (south of planet); W, Western Elongation; S, Superior Conjunction (north of planet).

VARIABLE STARS.

Minima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard time 6^h, etc.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1921 May							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.8			13 6					
RT Sculptor.	31.5	—26 13	9.6—10.5	0 12.3	4 6		11 22		19 14		27 6	
UU Androm.	38.5	+30 24	10.7—11.9	1 11.7	5 2		12 12		19 22		27 9	
U Cephei	0 53.4	+81 20	7.0— 9.0	2 11.8	5 5		12 16		20 4		27 15	
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	3 9		9 12		21 17		27 20	
TW Cassiop.	37.6	+65 19	8.2— 9.0	1 10.3	1 15		8 18		23 1		30 4	
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	5 8		12 5		19 1		25 22	
RZ Cassiop.	39.9	+69 13	6.9— 8.1	1 04.7	5 8		12 12		19 16		26 20	
TX Cassiop.	44.4	+62 22	9.4—10.1	2 22.2	9 1		17 19		26 14			
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	7 17		15 15		23 14		31 13	
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6								
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	4 21		10 14		22 1		27 19	
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	6 9		13 4		19 23		26 16	
λ Tauri	55.1	+12 12	3.3— 4.2	3 22.9	1 7		9 5		17 2		25 0	
RW Tauri	3 57.8	+27 51	7.1—<11	2 18.5	6 12		14 20		23 3		31 10	
RV Persei	4 04.2	+33 59	9.5—11.0	1 23.4	3 9		11 6		19 4		27 2	
RW Persei	13.3	+42 04	8.8—11.0	13 04.8	6 16				19 11			
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	7 1		16 12		25 22			
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1	6 0		18 20		31 6			
TT Aurigæ	5 02.8	+39 27	7.8— 8.7	0 16.0	7 13		14 5		20 21		27 13	
RY Aurigæ	11.5	+38 13	10.7—11.7	2 17.5	1 7		9 11		27 16		25 20	
RZ Aurigæ	42.9	+31 40	10.6—13.3	3 00.3	5 6		11 6		23 7		29 8	
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	7 18		16 10		25 3			
Z Orionis	50.2	+13 40	9.7—10.7	5 04.9	2 22		13 8		23 17			
SV Gemin.	54.6	+24 28	9.8—<11	4 00.2	3 17		11 17		19 18		27 18	
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	5 20		11 14		23 1		28 18	
U Columbæ	6 11.2	—33 03	9.2—10.0	2 19.2	3 10		9 0		20 5		25 20	
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8	7 15		15 20		24 1			
RW Monoc.	29.3	+ 8 54	9.0—10.8	1 21.7	1 19		9 10		17 1		24 16	
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0	6 17		18 22		31 3			
RU Monoc.	6 49.4	— 7 28	9.8—10.5	0 21.5	3 3		10 7		24 15		31 19	
R Can. Maj.	7 14.9	—16 12	5.8— 6.4	1 03.3	2 4		8 23		22 15		29 11	
RY Gemin.	21.7	+15 52	8.9—<10	9 07.2	4 9		13 16		22 23			
Y Camelop.	27.6	+76 17	9.5—12	3 07.3	1 16		8 7		21 12		28 3	
TX Gemin.	30.3	+17 08	10.0—11.9	2 19.2	3 15		12 0		20 10		28 20	
RR Puppis	43.5	—41 08	9.4—10.7	6 10.3	5 4		11 15		24 11		30 22	
V Puppis	7 55.4	—48 58	4.1— 4.8	1 10.9	7 5		14 11		21 18		29 0	
X Carinae	8 29.1	—58 53	7.9— 8.7	0 13.0	6 2		14 5		22 8		30 11	
S Cancri	8 38.2	+19 24	8.2—10	9 11.6	5 4		14 15		24 3			
RX Hydræ	9 00.8	— 7 52	9.1—10.5	2 6.8	7 16		14 12		21 8		28 4	
S Velorum	29.4	—44 46	7.8— 9.3	5 22.4	1 23		7 21		19 18		25 16	
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	5 23		12 17		19 11		26 5	
RR Velorum	10 17.8	—41 36	10.0—10.9	1 20.5	3 10		10 20		18 6		25 16	
SS Carinæ	10 54.2	—61 23	12.2—12.8	3 07.2	5 2		11 17		24 22		31 12	
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	3 20		12 15		21 10		30 5	
RW Urs. Maj.	35.4	+52 34	10.3—11.4	7 07.9	2 17		10 1		17 9		24 17	
Z Draconis	11 39.8	+72 49	9.9—13.6	1 08.6	3 20		10 14		24 4		30 23	
RZ Centauri	12 55.6	—64 05	8.5— 8.9	1 21.0	2 16		10 5		17 17		25 5	
RS Can. Ven.	13 06.3	+36 28	7.5—12.5	4 19.1	1 4		10 19		20 9		29 23	
SS Centauri	07.2	—63 37	8.8—10.4	2 11.5	7 18		15 5		22 21		30 8	
133926 Hydræ	13 39.0	—26 23	8.6—12.7	2 21.5	1 19		7 14		19 4		24 23	

Minima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1921							
					May							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
δ Libræ	14 55.6	— 8 07	4.8— 6.2	2 07.9	7 10	14 10	21 9	28 9				
U Coronæ	15 14.1	+32 01	7.6— 8.7	3 10.9	6 23	13 21	20 19	27 17				
TW Draconis	15 32.4	+64 14	7.3— 8.9	2 19.3	3 4	11 14	20 0	28 10				
SS Librae	15 43.4	—15 14	9.3—11.5	0 18.4	6 9	14 1	21 17	29 8				
SW Ophiuchi	16 11.1	— 6 44	9.2—10.0	2 10.7	5 18	13 2	20 10	27 19				
SX Ophiuchi	12.6	— 6 25	10.5—11.2	2 01.5	8 22	17 4	25 10					
R Aræ	31.1	—56 48	6.8— 7.9	4 10.2	3 11	12 8	21 4	30 1				
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1	3 8	13 0	24 2					
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	4 19	11 14	18 9	25 5				
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	7 5	15 14	24 0					
μ Herculis	13.6	+33 12	4.6— 5.4	2 01.2	6 15	12 19	25 2	31 6				
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	5 2	11 6	17 11	23 15				
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	7 12	14 21	22 6	29 15				
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	4 18	12 22	21 2	29 7				
TX Scorpii	48.6	—34 13	7.5— 8.2	0 22.6	4 11	12 0	19 13	27 2				
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	3 1	10 19	18 12	26 6				
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	6 17	14 17	22 16	30 16				
WX Sagittarii	53.6	—17 24	9.2—10.8	2 03.1	8 6	16 18	25 7					
WY Sagittarii	17 54.9	—23 1	9.5—10.6	4 16.0	4 15	13 23	23 8					
SX Draconis	18 03.0	+58 23	9.3—10.5	5 04.1	8 17	19 1	29 10					
RS Sagittarii	11.0	—34 08	5.9— 6.3	2 10.0	1 7	8 13	23 1	30 7				
V Serpentis	11.1	—15 34	9.5—11.1	3 10.9	5 2	12 0	18 22	25 19				
RZ Scuti	21.1	— 9 15	7.4— 8.3	15 03.2	7 3		22 6					
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	1 7	8 11	22 19	29 23				
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	2 1	9 3	23 9	30 12				
SX Sagittarii	39.7	—30 36	8.7— 9.8	2 01.8	6 16	16 0	23 8	31 15				
RR Draconis	40.8	+62 34	9.3—13	2 19.9	9 2	17 13	26 1					
RS Scuti	43.7	—10 21	9.3—10.3	0 15.9	1 23	8 15	21 21	28 13				
β Lyræ	46.4	+33 15	3.4— 4.1	12 21.8	8 22		21 20					
U Scuti	18 48.9	—12 44	9.1— 9.6	0 22.9	2 1	9 16	17 7	24 23				
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	4 16	12 6	19 20	27 9				
RV Lyræ	12.5	+32 15	11. —12.8	3 14.4	3 1	10 5	24 15	31 20				
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	8 0	16 23	25 22					
U Sagittæ	14.4	+19 26	6.5— 9.0	3 09.1	6 14	13 8	20 2	26 21				
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	7 7	14 16	22 1	29 9				
TT Lyræ	24.3	+41 30	9.4—11.6	5 05.8	1 3	5 9	16 21	22 3				
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	4 10	10 22	23 23	30 12				
SY Cygni	19 42.7	+32 28	10 —12	6 00.2	3 11	9 11	21 11	27 12				
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	7 4	13 19	20 10	27 2				
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	2 13	11 17	20 20	29 23				
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	4 17	13 3	21 13	28 23				
RW Capric.	12.2	—17 59	8.8—10.6	3 09.4	1 20	8 15	22 4	28 23				
UW Cygni	19.6	+42 55	10.5—13	3 10.8	6 14	13 12	20 9	27 7				
V Vulpec.	32.3	+26 15	8.2— 9.8	37 19.0			25 17					
W Delphini	33.1	+17 56	9.4—12.1	4 19.4	2 2	11 16	21 7	30 22				
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	4 22	14 2	23 7					
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	1 17	9 5	24 5	31 16				
WZ Cygni	49.3	+38 27	9.9—10.8	0 14.0	1 15	9 5	16 19	24 10				
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	2 13	12 15	22 18					
VVCygni	21 02.3	+45 23	12.1—13.8	1 11.4	6 22	14 7	21 16	29 1				
AE Cygni	09.0	+30 20	10.8—11.4	0 23.3	8 7	17 23	27 16					
RY Aquarii	14.8	—11 14	8.8—10.4	1 23.2	6 23	14 20	22 17	30 13				
RT Lacertæ	21 57.4	+43 24	9.1—10.5	5 01.7	2 23	13 3	23 6					
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3		8 11						
RW Lacertæ	22 40.6	+49 08	10.2—11.2	5 04.4	5 16	10 20	21 5	31 14				
8.1914 Pegasi	51.7	+32 41	10.0—10.6	5 06.4	4 19	15 8	20 15	31 4				
TT Androm.	23 08.7	+45 36	11.3—12.6	2 18.4	4 20	13 3	21 10	29 18				
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.3	7 22	15 11	22 23	30 13				
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	7 5	15 11	23 17	31 23				

Maxima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard time 6^h, etc.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1921 May					
	h m	° ′		d h	d h	d h	d h	d h	d h	d h
SX Cassiop.	0 05.5	+54 20	8.6— 9.2	36 13.7	2 7					
SY Cassiop.	0 09.8	+57 52	9.3— 9.9	4 1.7	1 17	9 20	17 0	26 3		
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	1 20	9 14	17 7	24 1		
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2		9 17		24 12		
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	4 16	12 15	20 13	28 12		
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	1 13	8 18	16 13	24 8		
TU Persei	3 01.8	+52 49	11.4—12.2	0 14.6	8 6	15 13	22 20	30 3		
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0	7		23			
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	3 9	11 23	20 13	29 3		
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	6 16	17 18	28 22			
RX Aurigæ	4 54.5	+39 49	7.2— 8.1	11 15.0	4 22	16 13	28 4			
SX Aurigæ	5 04.6	+42 02	8.0— 8.7	1 12.8	5 13	13 4	20 20	28 12		
SY Aurigæ	05.5	+42 41	8.4— 9.5	10 03.3		10 19	20 23	31 2		
Y Aurigæ	21.5	+42 21	8.6— 9.6	3 20.6	5 8	13 1	20 18	20 11		
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	4 6	9 19	20 21	31 22		
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	4 13	12 3	19 16	27 6		
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3	5 14					
RT Aurigæ	23.0	+30 33	5.1— 6.0	3 17.5	7 18	15 5	22 16	30 3		
RZ Camelop.	23.7	+67 06	11.0—13.0	0 11.5	1 5	8 9	22 19	30 1		
W Gemin.	29.2	+15 24	6.7— 7.5	7 22.0	3 1	10 23	18 21	26 19		
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	5 1	15 4	25 8			
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5			21 4			
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	4 9	12 8	20 6	28 5		
V Carinæ	8 26.7	—59 47	7.4— 8.1	6 16.7	3 4	9 21	23 6	29 23		
T Velorum	8 34.4	—47 01	7.6— 8.5	4 15.3	6 15	15 22	25 5			
V Velorum	9 19.2	—55 32	7.5— 8.2	4 08.9	9 8	18 2	26 19			
Z Leonis	9 46.4	+27 22	7.9— 9.6	59 00.0				30		
RR Leonis	10 02.1	+24 29	9.1—10.1	0 10.9	1 10	8 5	21 18	28 13		
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	4 7	10 22	24 3	30 17		
S Muscæ	12 07.4	—69 36	6.4— 7.3	9 15.8	2 17	12 9	22 1			
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7	5 22	13 21	21 21	29 20		
T Crucis	15.9	—61 44	6.8— 7.6	6 17.6	7 11	14 5	20 23	27 16		
R Crucis	18.1	—61 04	6.8— 7.9	5 19.8	5 5	11 1	22 17	28 12		
S Crucis	12 48.4	—57 53	6.5— 7.6	4 16.6	2 3	11 12	20 22	30 6		
W Virginis	13 20.9	— 2 52	8.7—10.4	17 06.5	1 20		19 2			
SS Hydræ	25.0	—23 08	7.4— 8.1	8 04.8	5 10	13 14	21 19	30 0		
RV Urs. Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	1 4	8 4	22 5	29 6		
ST Virginis	14 22.5	— 0 27	10.3—11.4	0 09.9	5 11	13 17	21 22	30 3		
V Centauri	25.4	—56 27	6.4— 7.8	5 11.9	5 22	11 10	22 10	27 22		
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	5 19	13 8	20 21	28 10		
RU Bootis	14 41.5	+23 44	12.8—14.3	0 11.9	7 20	15 6	22 16	30 2		
R Triang. Austr.	15 10.8	—66 08	6.7— 7.4	3 09.3	7 1	13 20	20 14	27 9		
S Triang. Austr.	15 52.2	—63 29	6.4— 7.4	6 07.8	3 11	9 19	22 11	28 18		
S Normæ	16 10.6	—57 39	6.6— 7.6	9 18.1	1 23	11 17	21 11	31 5		
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	1 3	10 0	18 20	27 17		
RV Scorpii	16 51.8	—33 27	6.7— 7.4	6 01.5	5 23	12 1	24 4	30 5		
X Sagittarii	17 41.3	—27 48	4.4— 5.0	7 00.3	7 2	14 2	21 3	28 3		
Y Ophiuchi	47.3	— 6 07	6.1— 6.5	17 02.9	8 20	25 23				
W Sagittarii	17 58.6	—29 35	4.3— 5.1	7 14.3	5 16	13 6	20 20	28 10		
Y Sagittarii	18 15.5	—18 54	5.4— 6.2	5 18.6	3 2	14 15	20 9	31 23		
U Sagittarii	26.0	—19 12	6.5— 7.3	6 17.9	2 21	9 15	23 3	29 21		
Y Scuti	32.6	— 8 27	8.7— 9.2	10 08.3	5 4	15 13	25 21			
Y Lyræ	34.2	+43 52	11.3—12.3	0 12.1	2 1	8 1	20 3	26 4		
RZ Lyræ	18 39.9	+32 42	9.9—11.2	0 12.3	2 11	8 14	20 20	26 23		

Maxima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1921							
					May							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
RT Scuti	18 44.1	—10 30	9.1— 9.7	0 11.9	4 8	10 7	22 5	28 3				
κ Pavonis	18 46.6	—67 22	3.8— 5.2	9 02.2	1 17	10 20	19 22	29 0				
U Aquilæ	19 24.0	— 7 15	6.2— 6.9	7 00.6	3 8	10 9	17 9	24 10				
XZ Cygni	30.4	+56 10	8.6— 9.3	0 11.2	3 18	10 18	17 18	24 17				
U Vulpec.	32.2	+20 07	6.5— 7.6	7 23.5		8 16	16 16	24 15				
SU Cygni	40.8	+29 01	6.2— 7.0	3 20.3	7 0	14 17	22 9	30 1				
η Aquilæ	47.4	+ 0 45	3.7— 4.5	7 04.2	4 13	11 17	18 21	26 1				
S Sagittæ	51.5	+16 22	5.6— 6.4	8 09.2	2 22	11 7	19 16	28 2				
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	6 6	12 14	18 22	25 5				
X Cygni	20 39.5	+35 14	6.0— 7.0	16 09.3	3 20	30 6						
T Vulpec.	47.2	+27 52	5.5— 6.1	4 10.5	4 1	12 22	21 19	30 16				
WY Cygni	52.3	+30 03	9.6—10.4	0 13.5	7 7	14 1	20 18	27 12				
RV Capric.	55.9	—15 37	9.2—10.1	0 10.7	2 13	9 6	15 23	22 17				
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4	5 12	20 6						
VY Cygni	21 00.4	+39 34	8.8— 9.5	7 20.6	5 13	13 9	21 6	29 3				
SW Aquarii	10.2	— 0 20	9.9—10.8	0 11.0	4 7	11 5	18 2	24 23				
VZ Cygni	21 47.7	+42 40	8.2— 9.2	4 20.7	3 15	13 9	23 2	27 23				
Y Lacertæ	22 05.2	+50 33	9.1— 9.6	4 07.8	4 21	13 13	22 5	30 20				
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	5 16	11 1	16 10	21 18				
Z Lacertæ	36.9	+56 18	8.2— 9.0	10 21.1	6 13	17 11	28 8					
RR Lacertæ	37.5	+55 55	8.5— 9.2	6 10.1	1 22	8 8	14 18	21 4				
V Lacertae	44.5	+55 48	8.5— 9.5	4 23.6	1 6	11 5	21 4	31 3				
X Lacertæ	22 45.0	+55 54	8.2— 8.6	5 10.7	5 18	11 5	16 16	22 2				
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	4 0	14 21	25 18	31 5				
RS Cassiop.	32.6	+61 52	9.0—11.0	6 07.1	7 4	13 11	19 18	26 1				
RY Cassiop.	47.2	+58 11	9.3—11.8	12 03.4	8 23	21 3						
V Cephei	23 51.7	+82 38	6.0— 7.0	0 23.9	5 21	12 21	19 21	26 20				

COMET NOTES.

Ephemeris of Pons-Winnecke Comet.—This ephemeris is based upon the elements below, all by Dr. Crommelin but the e and a.

T = 1921 June 15 ± 10^d
ω = 174°
π = 270°
☊ = 96°
i = 19° 30′
Log e = 9.84599
Log a = 0.52929
μ = 570″.27
P = 2272.60 days

EPHEMERIS.

1921	α h	α m	δ °	δ ′	Log r	Log Δ
April 14	15	41	+41	26	0.12170	9.68996
" 18	15	48	+43	9	0.11078	9.66074
" 22	15	57	+44	51	0.09990	9.63021
" 26	16	6	+46	30	0.08912	9.59830
" 30	16	17	+48	8	0.07852	9.56439
May 4	16	29	+49	42	0.06818	9.52816
" 8	16	44	+51	13	0.05822	9.48918
" 12	17	2	+52	37	0.04870	9.44669

F. E. SEAGRAVE.

As the date assumed for the time of perihelion passage may be in error the

ephemeris is somewhat uncertain. It is, however, quite probable that the comet will be very near the earth from about June 22 to about June 27. If the date of perihelion should be June 22, the comet would on that day be only a little more than 3,000,000 miles from the earth, and on June 26 less than 2,000,000 miles. Because of this close approach Dr. Crommelin thinks that it is quite safe to prophesy a good shower of meteors in the latter part of June, although the chances of actual collision with the comet are not very great. In 1916 a stream of meteors was found, whose connection with this comet was established by Mr. Denning and Dr. Olivier. More definite predictions could be made except for the fact that the comet passed close to Jupiter at its last aphelion and the perturbations due to this planet have not as yet been determined.

Comet Taylor-Skjellerup.—The comet whose discovery was announced last month was first seen by Mr. C. J. Taylor on Dec. 8, and independently found by Mr. Skjellerup on Dec. 11. It should be called Taylor-Skjellerup.

It has been well observed, but has not presented any physical features of special interest. It was a fairly large, round, nebulous object, with an ill-defined nucleus of magnitude 10½. The latter on Jan. 5 was noted at Heidelberg as being 24″ long in E.-W. direction.

The following orbit is by M. Ebell from observations on Dec. 13, 19 and Jan. 3:

$$\begin{aligned} T &= 1920\ \text{Dec.}\ 11.00476\ \text{G. M. T.} \\ \omega &= 340^\circ\ 50'\ 53''.0 \\ \Omega &= 107\ \ 46\ \ 26\ .4 \quad 1920.0 \\ i &= \ \ 22\ \ \ 5\ \ 26\ .9 \\ \log q &= 0.060159 \end{aligned}$$

(A. C. D. C. in *The Observatory* for February 1921.)

New Comet.—On December 13, 1920, a comet was announced from Cape Town, South Africa, having been discovered by Skjellerup. On March 13 of this year another comet was announced from Cape Town, having been discovered by Reid. Two Harvard College Observatory Bulletins and a telegram contain the information which has been received concerning this new comet.

H. C. O. Bulletin 744:

A cablegram from M. G. Lecointe, Director of the Central Bureau of Astronomical Telegrams, at Bruxelles, announces the discovery of a comet by Reid, at Capetown, on March 13. The same message contains the following position from an observation made at Johannesburg:

March 14.6187 G.M.T.
R.A. $20^h\ 14^m\ 35^s.0$
Dec. $-18^\circ\ 28'\ 48''$

The comet was of ninth magnitude.

H. C. O. Bulletin 745:

The following position of Reid's Comet has been received here:

G. M. T.	R. A. (h m s)	Dec. (° ′ ″)	Observer
March 18.7012	20 16 56.7	−16 20 40	Renaux.

The comet is referred to in this message as having been discovered by Hoal. It is evidently identical with Reid's Comet.

Telegram:

Cambridge, Mass.

Lecoint cables Reid comet observed by Renaux March 25.6877 Greenwich mean time, ascension 20 hrs. 20 min. 52.7 sec. South 11° 52′ 9″.

(Signed) S. I. Bailey.

NOTES FOR OBSERVERS.

Monthly Report of the American Association of Variable Star Observers, January 20, 1921 to February 20, 1921.

This is an unusually good mid-winter report, and shows that observers have been taking advantage of every opportunity to keep up the good work. Messrs. McAteer and Peltier are in the van, each with lists exceeding the hundred mark and containing stars in practically every hour of R. A. Messrs. Chandra, Janczewski and Lacchini from abroad, and Miss Young from this country add materially to the total. Messrs. Dawson and Tapia contribute their recent work of southern variables; Mr. Dawson has been made the Acting Director of the National Observatory of La Plata. Mr. John Ellsworth, of Lyon, France, sends his observations of Nova Cygni, and a second list was received too late for inclusion in this report.

Through the generosity of one of our Patrons the Association has been able to distribute 100 additional copies of the 1920 reprint to the principal observatories and libraries of the world, thus making the results of our work more readily accessible. A number of students in astronomy at Mt. Holyoke College, under the direction of Professor Young, have undertaken the compilation of ten day means from the published observations of the Association for the years 1918-1920. Mr. William Hodgkinson of Framingham, Mass., is to have the use of the 6-inch equatorial at the Harvard Observatory for variable star work.

The second announcement of the Chart Committee, which should be in the hands of all members by this time, constitutes a big step in achieving the ambitions of this committee to bring all of our charts up to date. The stars from 16 to 20 hrs. R. A. are included in this report. Some improvements and corrections have been made which it is important for all to note. Attention is especially called to the plan which is under consideration to supply members with sets of photographic reproductions of the charts of the Bonn Durchmusterung, approximately 8 by 10 inches in size. The complete set will comprise 64 charts and from present indications will cost $16.00 per set. Before undertaking this scheme the committee thinks it advisable to learn how many members and others would care to subscribe. Those wishing to learn further of this matter can secure full particulars and a sample chart from the chairman of the Chart Committee, Mr. D. B. Pickering, 171 So. Burnett St., East Orange, N. J.

The following new members have been elected by the Council, and we welcome them to the ranks:

P. R. Allen, Auburndale, Mass.
W. Downs, Riverhead, N. Y.
A. Mork, Peoria, Ill.
E. H. Weeks, Riverhead, N. Y.
A. L. Gowland, Buenos Aires, Argentina.
J. W. Thompson, Cambridge, Md.

SS Aurigae, 060547, began a slow rise to maximum on Feb. 12, this proving to be a "narrow" type maximum, No. 89. The next one is due about the end of April. U Geminorum is due to rise about March 15, and SS Cygni about April 5. There is a tendency apparently to neglect some of the circumpolar variables, such as 083350 X Ursae Maj., 093178 Y Draconis, and 141567 U Urs.

VARIABLE STAR OBSERVATIONS, January 20 to February 20, 1921.
January 0 = 2422690 February 0 = 2422721

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
001032	S Sculptoris	2631.6	7.7	Dw,	2665.6	6.8	Tp,	2667.7	6.9	Dw,	2669.7	6.6	Dw,
		2673.6	6.5	Tp,	2696.6	6.6	Tp,	2696.6	6.5	Dw,	2698.6	6.6	Dw.
001046	X Androm.	2713.6	10.2	M,	2719.5	10.0	Ba,	2733.5	11.8	Pi,	2735.5	11.6	B.
001620	T Ceti	2718.3	6.7	L.									
001726	T Androm.	2688.1	10.9	Ch,	2713.6	8.6	M,	2717.6	9.0	Pt,	2719.5	8.4	Ba,
		2735.5	8.3	B.									
001755	T Cassiop.	2712.4	8.3	L,	2713.5	8.8	M,	2716.6	8.9	Pt,	2719.5	8.0	Ba,
		2719.7	8.2	Bs,	2727.8	7.8	Bs,	2729.6	7.9	B,	2731.7	7.7	Bs,
		2733.5	8.4	Pi,	2739.6	8.6	Ya.						
001838	R Androm.	2665.2	8.6	Ch,	2670.2	8.8	Ch,	2691.2	9.1	Ja,	2697.2	9.1	Ja,
		2713.6	9.1	M,	2716.6	9.3	Pt,	2719.5	8.9	Ba,	2727.5	9.5	Ya,
		2733.5	9.6	Pi,	2735.5	9.1	B.						
001909	S Ceti	2664.1	12.0	Ch,	2688.1	11.6	Ch,	2713.5	*10.2*	Ya,	2716.5	10.6	Pt,
		2719.3	11.4	L.									
*002438*a	T Sculptoris	2631.6	11.1	Dw,	2665.6	13.0	Tp,	2667.7	12.9	Dw,			
		2669.7	12.8	Dw,	2696.6	12.7	Dw,	2696.6	12.6	Tp,			
		2698.6	12.5	Dw,	2700.6	12.6	Tp.						
002546	T Phoenicis	2631.6	14.0	Dw,	2667.7	*13.6*	Dw,	2669.7	*13.8*	Dw,			
		2696.6	*13.7*	Tp,	2698.6	*13.5*	Dw,	2700.6	*13.6*	Tp.			
003179	Y Cephei	2719.5	*13.5*	Ba.									
004047	U Cassiop.	2713.6	10.0	M,	2716.6	10.0	Pt,	2718.6	9.6	Y,	2719.5	9.1	Ba,
		2727.6	8.6	Hl,	2729.5	8.6	Y,	2733.5	9.0	Pi,	2733.6	8.8	B,
		2739.6	9.6	Ya.									
004132	RW Androm.	2719.6	*13.8*	Ba.									
004435	V Androm.	2707.6	11.8	B,	2719.6	12.8	Ba,	2733.5	*12.0*	Pi.			
004533	RR Androm.	2719.6	12.0	Ba.									
004746	RV Cassiop.	2719.6	9.0	Ba.									
004958	W Cassiop.	2707.5	8.6	B,	2713.6	8.2	M,	2716.6	9.0	Pt,	2719.6	8.9	Ba,
		2729.5	9.2	K,	2733.5	9.4	Pi,	2738.5	9.0	Gd.			
010940	U Androm.	2713.6	*11.2*	M,	2733.5	*11.8*	Pi.						
011041	UZ Androm.	2713.6	*11.2*	M.									
011208	S Piscium	2729.6	*13.0*	Y.									
011272	S Cassiop.	2721.3	*12.6*	Rk.									
012350	RZ Persei	2718.6	10.7	Y,	2733.5	10.8	Pi.						
012502	R Piscium	2729.6	*13.2*	Y.									
013238	RU Androm.	2675.2	10.0	Ch,	2713.6	10.7	M,	2716.6	10.9	Pt,	2733.6	*11.6*	Pi,
		2735.6	12.5	B.									
013338	Y Androm.	2661.2	*11.0*	Ch,	2713.6	*11.5*	M,	2733.6	11.6	Pi.			
014958	X Cassiop.	2707.6	10.1	B,	2716.6	10.6	Pt,	2727.5	11.1	M,	2729.5	10.3	Y,
		2733.6	10.8	Pi.									
015354	U Persei	2716.6	8.3	Pt,	2727.5	8.4	M,	2727.6	9.5	Hl,	2733.6	7.8	Pi,
		2733.6	8.9	B,	2735.6	9.9	Hl.						
015912	S Arietis	2713.5	*9.9*	M,	2718.6	12.2	B,	2736.5	12.8	Ba.			
021024	R Arietis	2718.3	13.5	L,	2727.5	12.0	M,	2736.5	*12.5*	Ba.			
021403	o Ceti	2633.1	9.2	Ch,	2713.5	9.1	Sz,	2713.5	9.0	M,	2716.5	9.1	Sz,
		2716.6	9.4	Pt,	2716.6	9.5	Ya,	2719.6	8.8	Ba,	2731.8	9.2	Bs,
		2734.5	8.7	Sz,	2736.5	8.7	Ba.						
021558	S Persei	2718.6	9.3	B,	2733.6	10.7	Pi.						
022150	RR Persei	2713.6	10.0	M,	2718.6	10.0	Y,	2729.5	10.0	Y,	2733.6	10.4	Pi,
		2735.6	10.1	B.									
022813	U Ceti	2661.2	7.5	Ch,	2671.1	7.3	Ch,	2681.1	7.5	Ch,	2716.6	9.0	Pt.
		2716.6	8.7	Ya,	2729.6	9.0	Y.						
022980	RR Cephei	2718.4	*12.9*	L.									

VARIABLE STAR OBSERVATIONS, January 20 to February 20, 1921—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
023133	R Trianguli	2713.6	10.5	M,	2716.6	10.2	Pt.						
024356	W Persei	2690.7	9.5	Mu,	2713.6	9.0	M,	2716.6	9.8	Pt,	2716.6	9.3	Ya,
		2727.5	9.5	Ya,	2733.6	9.8	Pi,	2734.6	10.2	Ps,	2735.6	9.1	B,
		2736.5	9.0	Ba,	2738.5	9.2	Gd,	2739.5	9.1	Cl.			
025050	R Horologii	2631.7	12.4	Dw,	2667.7	12.9	Dw,	2669.7	12.9	Dw,			
		2673.6	11.9	Tp,	2677.7	12.7	Dw,	2696.6	12.8	Dw,			
		2696.6	12.3	Tp,	2698.6	12.8	Dw.						
025751	T Horologii	2631.7	8.8	Dw,	2667.7	10.8	Dw,	2669.7	11.2	Dw,			
		2673.6	11.4	Tp,	2677.7	11.8	Dw.						
030514	U Arietis	2729.6	12.6	Y,	2736.5	13.0	Ba.						
031401	X Ceti	2699.4	9.7	L,	2717.6	9.0	Pt.						
032043	Y Persei	2713.6	8.7	M,	2717.7	8.6	Pt,	2735.6	8.2	B,	2735.6	9.4	Ya.
032335	R Persei	2717.7	8.8	Pt,	2727.6	9.5	Ya,	2727.6	10.5	Hl,	2733.6	10.3	B,
		2733.6	9.8	Pi,	2736.5	10.5	Ba.						
033352	U Camel.	2713.6	7.6	M.									
034625	U Eridani	2631.7	13.8	Dw,	2667.7	*14.2*	Dw,	2696.6	*13.4*	Dw,			
		2736.5	*12.6*	Ba.									
035124	T Eridani	2631.7	9.6	Dw,	2667.7	8.7	Dw,	2669.7	8.2	Dw,	2673.6	8.2	Tp,
		2677.7	8.6	Dw,	2696.6	9.3	Dw,	2696.6	9.2	Tp,	2698.6	9.4	Dw,
		2736.5	11.6	Ba.									
035915	V Eridani	2736.5	8.6	Ba.									
040725	W Eridani	2631.7	9.4	Dw,	2667.7	8.6	Dw,	2669.7	8.6	Dw,	2673.6	8.5	Tp,
		2677.7	8.6	Dw,	2696.6	8.8	Dw,	2696.6	8.7	Tp,	2698.6	8.6	Dw.
041619	T Tauri	2736.5	9.8	Ba.									
042209	R Tauri	2717.6	11.4	Pt,	2718.6	11.6	Y,	2733.6	*11.3*	Po,	2736.5	12.0	Ba.
042215	W Tauri	2792.6	11.3	Yo,	2707.6	10.1	Yo,	2716.5	10.4	Sz,	2716.6	9.5	Yo,
		2717.6	9.5	Pt,	2727.6	9.7	M,	2733.7	9.6	Po,	2734.5	10.0	Pi,
		2734.5	10.3	Sz,	2736.5	9.8	Ba.						
042309	S Tauri	2693.6	*12.0*	Pw,	2718.6	*13.0*	Y,	2736.6	*12.5*	Ba.			
043065	T Camelop.	2693.6	*11.0*	Pw,	2713.6	*11.5*	M,	2718.4	12.3	L.			
043263	R Reticuli	2631.7	13.2	Dw,	2667.7	12.8	Dw,	2696.6	11.5	Dw,			
		2696.6	11.1	Tp.									
043274	X Camelop.	2693.6	8.5	Pw,	2713.6	11.4	M,	2715.5	12.1	B,	2718.6	12.0	Y,
		2729.6	12.0	Y,	2734.8	12.6	Pt,	2736.6	12.5	Ba.			
043562	R Doradus	2667.7	6.2	Dw,	2696.6	6.2	Dw,	2696.6	5.8	Tp.			
043738	R Caeli	2631.7	11.4	Dw,	2667.7	8.1	Dw,	2669.7	8.3	Dw,	2673.6	8.0	Tp,
		2677.7	8.0	Dw,	2696.6	8.4	Dw,	2696.6	7.8	Tp,	2698.6	8.4	Dw.
044349	R Pictoris	2631.7	8.3	Dw,	2667.7	8.0	Dw,	2669.7	8.0	Dw,	2673.6	7.3	Tp,
		2677.7	7.3	Dw,	2696.6	6.8	Tp.						
044617	V Tauri	2735.6	9.2	Pi.									
045307	R Orionis	2718.6	13.2	Y,	2729.6	12.6	Y,	2736.6	12.9	Ba.			
045514	R Leporis	2664.1	9.5	Ch,	2712.4	8.2	L,	2713.6	8.3	M,	2717.6	8.5	Pt,
		2718.3	8.4	Rk,	2728.5	8.2	B,	2734.6	9.5	Ps,	2735.5	8.6	Ya,
		2736.6	7.5	Ba.									
050003	V Orionis	2718.6	12.6	Y,	2736.6	12.2	Ba.						
050022	T Leporis	2717.6	9.0	Pt,	2727.6	9.0	Ya,	2728.5	8.6	B,	2736.6	8.7	Ba.
050953	R Aurigae	2693.6	*11.0*	Pw,	2707.6	10.3	Pw,	2727.6	*12.0*	Hl,	2733.6	*12.1*	Pi,
		2735.6	*11.4*	Ya.									
051247	T Pictoris	2631.7	8.2	Dw,	2667.7	9.2	Dw,	2669.7	9.3	Dw,	2673.6	9.2	Tp,
		2677.7	9.4	Dw,	2696.6	12.6	Tp.						
051533	T Columbae	2631.7	11.2	Dw,	2667.7	12.1	Dw,	2669.7	11.7	Dw,			
		2673.6	12.6	Tp,	2677.7	11.9	Dw,	2696.6	10.1	Tp.			
052034	S Aurigae	2699.3	9.8	L,	2714.6	9.4	Pw,	2727.6	8.5	Hl,	2733.7	9.2	Po,
		2735.6	9.3	Pi,	2735.6	9.3	Ya.						

VARIABLE STAR OBSERVATIONS, January 20 to February 20, 1921—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
052036	W Aurigae	2699.4	12.1	L.									
052404	S Orionis	2713.6	*11.5*	M,	2741.6	11.8	M.						
053005a	T Orionis	2706.4	11.0	L,	2712.3	11.0	L,	2713.6	10.2	M,	2717.6	10.0	Pt,
		2718.4	9.9	L,	2728.5	10.7	B,	2735.5	*11.4*	Ya,	2738.5	10.2	Gd,
		2741.6	10.0	M.									
053068	S Camelop.	2713.6	8.6	M,	2734.9	8.2	Pt.						
053326	RR Tauri	2694.5	11.5	Ja,	2697.3	11.0	Ja,	2699.3	10.8	Ja,	2701.2	11.0	Ja,
		2716.3	11.8	Ja,	2729.5	10.4	Cl.						
053531	U Aurigae	2693.6	*12.0*	Pw,	2700.6	*11.0*	Pw,	2707.6	*13.0*	Pw,			
		2734.6	*12.0*	Pw,	2735.8	11.5	Pt,	2739.5	*10.4*	Ya.			
054319	SU Tauri	2664.2	9.2	Ch,	2679.5	9.5	K,	2706.4	9.5	L,	2706.5	9.4	K,
		2712.3	9.7	L,	2716.6	9.6	Pt,	2718.4	9.7	L,	2718.5	9.5	B,
		2719.5	9.6	Ba,	2727.6	9.7	Po,	2729.5	9.4	Cl,	2732.6	9.5	Pt,
		2735.5	9.4	Pt,	2735.6	9.5	Pi,	2736.5	9.5	Ba,	2736.5	9.4	Pt,
		2737.5	9.3	Pt,	2739.5	9.5	Cl.						
054615a	Z Tauri	2718.6	12.7	Y.									
054615b	RS Tauri	2718.6	9.0	Y.									
054615c	RU Tauri	2718.6	12.1	Y.									
054629	R Columbae	2631.7	10.6	Dw,	2667.7	9.9	Dw,	2673.6	10.1	Tp.			
		2677.7	9.9	Dw,	2696.6	10.4	Tp.						
054920	U Orionis	2664.2	9.5	Ch,	2707.6	9.7	Pw,	2716.5	*11.6*	Sz,	2717.6	11.4	Pt,
		2727.6	*11.0*	Po,	2734.6	*12.0*	Hl,	2735.6	11.6	Pi.			
054974	V Camelop.	2693.6	*11.0*	Pw,	2715.6	*13.1*	B,	2721.5	*13.8*	B,	2729.6	*13.0*	Y,
		2734.6	*12.0*	Hl,	2736.6	*13.0*	Ba.						
055353	Z Aurigae	2733.6	10.4	Pi,	2735.6	10.2	Ya,	2735.8	10.4	Ya.			
055686	R Octantis	2631.7	11.3	Dw,	2667.7	11.8	Dw,	2673.6	12.4	Tp,			
		2677.7	12.1	Dw,	2696.6	12.6	Tp.						
060450	Z Aurigae	2731.6	12.0	Ro,	2733.7	11.1	Po.						
060547	SS Aurigae	2661.1	11.0	Ch,	2667.1	10.9	Ch,	2668.2	10.5	Ch,	2669.2	10.7	Ch,
		2670.2	10.8	Ch,	2671.2	10.9	Ch,	2672.1	11.0	Ch,	2673.2	11.2	Ch,
		2674.2	11.5	Ch,	2675.2	11.8	Ch,	2679.5	*11.6*	K,	2691.3	*12.6*	Ja,
		2693.6	11.5	Pw,	2694.2	*13.3*	Ja,	2697.3	*12.6*	Ja,	2699.3	*13.3*	Ja,
		2699.3	*12.4*	L,	2701.2	*12.6*	Ja,	2706.2	*12.6*	Ja,	2706.3	*12.4*	L,
		2706.5	*12.0*	K,	2708.3	12.7	Rk,	2715.2	13.0	Ja,	2715.5	*13.5*	B,
		2715.5	*12.4*	Pt,	2716.3	13.5	Ja,	2716.5	*12.0*	K,	2716.6	*12.6*	Pt,
		2717.5	*12.4*	Pt,	2718.3	*13.7*	L,	2718.5	*13.3*	Y,	2718.5	*12.6*	Pt,
		2718.5	*13.9*	B,	2719.5	*13.3*	Ja,	2720.4	*13.3*	Ja,	2720.6	*13.0*	L,
		2721.5	*14.0*	B,	2724.7	*12.4*	Pt,	2729.5	*12.4*	Cl,	2729.5	*12.4*	K,
		2729.5	*13.3*	Y,	2732.8	*12.6*	Pt,	2733.6	*12.4*	Pi,	2733.8	12.8	Pt,
		2734.6	*12.0*	Hl,	2734.8	12.2	Pt,	2734.8	12.0	E,	2735.5	11.8	Pt.
		2735.6	11.8	Pi,	2735.8	11.3	M,	2736.5	10.9	Cl,	2736.5	11.0	Pt.
		2736.6	11.5	B,	2736.6	11.2	Ba,	2736.8	10.8	M,	2737.5	11.0	Ba,
		2737.5	10.6	Pt,	2738.8	11.2	M,	2739.5	*11.0*	Cl,	2739.5	*11.2*	Ya,
		2741.6	12.7	M.									
063308	R Monoc.	2728.6	11.7	B,	2735.6	11.3	Hl.						
063558	S Lyncis	2734.9	12.1	Pt,	2736.5	12.3	B.						
064030	X Gemin.	2721.6	11.9	B,	2735.6	12.5	Pi.						
064707	W Monoc.	2717.6	10.7	Pt.									
064932	Nova Gem.II	2733.7	*11.3*	Po.									
065111	Y Monoc.	2718.6	11.7	Y,	2727.7	*11.2*	Po,	2735.6	*12.0*	Pi,	2737.5	*10.9*	Ya.
065208	X Monoc.	2737.5	8.2	Ya.									
065355	R Lyncis	2729.6	13.5	Y	2734.6	*12.0*	Hl.						
070122a	R Gemin.	2660.2	7.7	Ch,	2672.1	8.0	Ch,	2700.6	8.8	Pw,	2714.6	9.0	Pw,
		2716.8	9.5	M,	2717.6	9.4	Pt,	2721.6	9.2	B,	2727.7	9.5	Po.
070122b	Z Gemin.	2660.2	10.7	Ch,	2672.1	11.2	Ch,	2714.6	9.7	Pw,	2716.8	*11.6*	M,
		2721.6	12.3	B,	2735.8	12.5	Pt.						

VARIABLE STAR OBSERVATIONS, January 20 to February 20, 1921—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
070122c	TW Gemin.	2714.6	9.9	Pw,	2716.8	8.2	M,	2721.6	8.0	B.			
070310	R Canis Min.	2712.4	8.2	L,	2735.6	8.3	Pi,	2739.6	8.5	Ya.			
071044	L_2 Puppis	2688.2	4.2	Ch.									
071713	V Gemin.	2717.6	11.6	Pt,	2735.6	11.5	Pi.						
072708	S Canis Min.	2666.2	11.5	Ch,	2693.6	*11.0*	Pw,	2704.3	*10.0*	Rk,	2716.5	*10.0*	Sz,
		2718.3	*10.0*	Rk,	2718.4	12.7	L,	2720.4	*11.7*	Pe,	2721.3	*10.0*	Rk,
		2731.6	12.0	Ro,	2734.6	12.0	Ro.						
072811	T Canis Min.	2735.8	11.6	Pt.									
073508	U Canis Min.	2700.6	10.8	Pw,	2717.6	11.8	Pt,	2729.6	12.8	Y.			
073723	S Gemin.	2707.6	*12.0*	Pw,	2734.6	*12.0*	Hl,	2735.6	12.2	Pi.			
074323	T Gemin.	2735.6	10.2	Pi.									
074922	U Gemin.	2674.2	*12.3*	Ch,	2691.5	*13.3*	Ja,	2694.5	*12.3*	Ja,	2699.4	*13.3*	Ja,
		2699.6	*13.7*	L,	2701.4	*13.3*	Ja,	2707.6	13.2	Pw,	2708.3	*10.9*	Rk,
		2712.3	*11.0*	L,	2715.2	*12.3*	Ja,	2715.5	*12.4*	Pt,	2716.6	*13.3*	Pt,
		2717.5	*13.3*	Pt,	2717.5	*12.4*	Y,	2718.3	14.0	L,	2718.5	*12.4*	Pt,
		2718.6	*13.3*	Y,	2718.6	14.0	B,	2719.4	*13.3*	Ja,	2719.5	13.9	Ba,
		2720.4	*13.3*	Ja,	2720.6	*13.3*	L,	2721.6	14.0	B,	2728.5	*13.7*	Y,
		2728.6	*13.9*	B,	2732.6	*13.3*	Pt,	2733.6	*12.4*	Pi,	2733.8	*12.3*	Pt,
		2734.6	*12.0*	Hl,	2734.8	*12.4*	E,	2734.8	*13.3*	Pt,	2735.5	*12.4*	Pt,
		2735.6	*13.3*	Pi,	2735.6	*13.5*	B,	2735.8	*12.4*	M,	2735.9	*12.4*	E,
		2736.5	*13.3*	Ba,	2736.5	*12.3*	Pt,	2737.8	*13.3*	Pt.			
075612	U Puppis	2718.6	*13.0*	Y.									
081112	R Cancri	2666.2	11.3	Ch,	2717.6	10.1	Pt,	2718.4	10.4	L,	2721.6	9.5	B,
		2734.8	9.6	E,	2735.6	8.5	Hl,	2736.6	9.1	Ba.			
081617	V Cancri	2691.5	13.0	Ja,	2699.4	13.3	Ja,	2734.8	11.1	E,	2734.9	11.0	Pt,
		2736.6	10.7	Ba.									
082405	RT Hydrae	2699.7	8.2	L.									
083019	U Cancri	2734.8	*11.9*	E,	2736.6	*13.4*	Ba.						
083350	X Urs. Maj.	2735.6	*12.0*	Hl,	2735.8	11.7	Pt,	2736.6	12.0	Ba.			
084803	S Hydrae	2660.3	7.6	Ch,	2677.4	8.5	Ch,	2718.6	10.9	Pt,	2722.6	*10.2*	Sz,
		2727.6	*11.0*	M,	2735.6	11.0	Hl.						
085008	T Hydrae	2668.2	10.4	Ch,	2699.7	11.7	L.						
085120	T Cancri	2718.6	8.6	Pt,	2735.6	8.6	Hl.						
090151	V Urs. Maj.	2690.7	10.1	Mu,	2729.5	10.1	K,	2729.5	10.4	B.			
090425	W Cancri	2720.7	11.0	L.									
091868	RW Carinae	2631.7	12.1	Dw,	2667.7	10.1	Dw,	2673.6	9.6	Tp,	2696.6	9.5	Tp,
		2701.7	9.2	Tp.									
092962	R Carinae	2631.7	7.3	Dw,	2667.8	9.1	Dw,	2673.6	9.0	Tp,	2696.6	9.2	Tp,
		2701.7	9.1	Tp.									
093014	X Hydrae	2735.6	9.5	Hl.									
093178	Y Draconis	2729.6	12.2	Y.									
093934	R Leonis Min.	2668.3	*10.5*	Ch,	2712.4	9.0	L	2718.7	8.8	Pt.			
094023	RR Hydrae	2667.8	9.7	Dw,	2677.7	9.5	Dw.						
094211	R Leonis	2668.2	7.2	Ch,	2690.7	6.1	Mu,	2717.6	5.7	Pt,	2720.4	6.2	Pe,
		2726.7	6.6	Bs,	2727.7	6.4	Bs,	2729.7	6.2	Bs,	2730.8	5.9	Bs,
		2734.6	7.1	Ps,	2734.6	6.1	Ro.	2736.6	6.1	Ro,	2736.8	6.9	M,
		2739.5	6.7	Cl.									
094262	*l* Carinae	2667.8	4.1	Dw,	2673.6	4.0	Tp,	2677.8	4.3	Dw,	2696.6	3.9	Dw,
		2701.7	3.8	Tp.									
094622	Y Hydrae	2735.8	6.7	Pt.									
095421	V Leonis	2698.5	12.5	Ja,	2705.5	12.2	Ja,	2718.7	11.1	Pt,	2719.4	11.6	Ja,
		2736.8	9.4	M.									
100661	S Carinae	2631.7	6.5	Dw,	2667.8	5.8	Dw,	2677.7	5.8	Dw,			
		2696.6	6.7	Dw,	2696.6	6.0	Tp,	2701.7	6.3	Tp.			

VARIABLE STAR OBSERVATIONS, January 20 to February 20, 1921—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
103212	U Hydrae	2699.7	5.4	L,	2719.6	5.2	L.						
103769	R Urs. Maj.	2668.3	7.8	Ch,	2716.8	10.1	M,	2718.7	9.3	Pt,	2719.6	9.3	Ba,
		2722.6	10.1	Sz,	2729.5	10.5	K,	2734.6	11.1	Ps,	2734.6	10.2	Sz.
104620	V Hydrae	2671.5	8.2	Ch,	2719.6	7.1	L,	2733.8	7.7	Pt,	2735.6	9.3	Hl.
104814	W Leonis	2718.6	10.0	Y,	2718.7	10.1	Pt,	2729.6	9.8	Y.			
110506	S Leonis	2736.8	10.4	M,	2737.8	10.2	Pt.						
114441	X Centauri	2667.8	13.0	Dw,	2696.6	12.5	Tp.						
115919	R Com. Ber.	2736.6	*12.2*	M.									
120012	SU Virginis	2691.5	10.5	Ja,	2693.7	10.7	Ja,	2698.5	11.0	Ja,	2705.5	11.3	Ja,
		2719.4	11.8	Ja.									
121418	R Corvi	2734.9	13.5	Pt,	2735.8	*11.3*	M.						
122001	SS Virginis	2719.6	6.6	L,	2736.8	7.9	M.						
122532	T Canum Ven.	2716.8	9.7	M,	2718.7	9.1	Pt.						
122803	Y Virginis	2699.7	10.6	L.									
123160	T Urs. Maj.	2670.5	*11.0*	Ch	2716.8	10.7	M,	2717.7	11.5	Bs,	2718.7	11.1	Pt,
		2719.6	12.0	Ba,	2722.6	*10.8*	Sz,	2729.5	10.9	K,	2735.8	9.7	M,
		2736.5	9.8	Ba.									
123307	R Virginis	2733.8	9.7	Pt,	2736.8	9.5	M.						
123459	RS Urs. Maj.	2670.5	8.8	Ch,	2718.7	10.5	Pt,	2718.7	10.8	Sz,	2719.6	10.4	Ba,
		2722.6	10.4	Sz,	2726.7	10.2	Bs,	2729.5	10.9	K,	2734.7	*9.9*	Sz,
		2735.8	11.5	M,	2736.5	11.6	Ba						
123961	S Urs. Maj.	2670.5	8.2	Ch,	2688.2	8.3	Ch,	2712.7	8.7	L,	2716.8	8.7	M,
		2718.7	8.7	Pt,	2718.7	8.9	Sz,	2719.6	8.3	Ba,	2722.6	9.0	Sz,
		2726.8	8.9	Bs,	2729.5	9.4	K,	2734.7	9.2	Sz,	2735.8	9.0	M,
		2736.5	9.0	Ba.									
124204	RU Virginis	2693.7	12.7	Ja.									
124606	U Virginis	2693.7	10.8	Ja,	2719.5	*11.5*	Ja.						
130212	RV Virginis	2735.9	12.3	Pt.									
131283	U Octantis	2631.7	12.8	Dw,	2667.7	13.3	Dw,	2673.6	13.4	Tp.			
		2677.7	13.4	Dw.									
132422	R Hydrae	2666.4	4.8	Ch,	2667.8	5.1	Dw,	2699.7	6.3	L,	2719.7	5.6	L,
		2732.8	6.5	Pt.									
132706	S Virginis	2732.8	6.6	Pt,	2736.8	6.5	M.						
133273	T Urs. Min.	2735.8	*12.0*	M.									
133633	T Centauri	2667.8	6.6	Dw,	2701.7	6.0	Tp.						
134236	RT Centauri	2667.8	9.1	Dw.									
134440	R Canum Ven.	2716.8	10.6	M,	2718.7	10.6	Pt,	2729.6	9.5	Y.			
134677	T Apodis	2667.8	13.8	Dw.									
135908	RR Virginis	2733.8	12.6	Pt.									
140959	R Centauri	2667.8	6.9	Dw,	2677.7	7.4	Dw.						
141567	U Urs. Min.	2677.4	12.0	Ch,	2718.7	11.4	Pt,	2736.8	10.5	M.			
141954	S Bootis	2677.4	9.3	Ch,	2712.4	8.4	L,	2718.7	8.4	Pt,	2734.7	8.2	Sz.
142205	RS Virginis	2693.7	*11.9*	Ja.									
142539	V Bootis	2712.5	9.0	L,	2716.8	9.5	M,	2732.8	10.0	Pt,	2735.9	9.6	E.
143227	R Bootis	2671.4	10.6	Ch,	2733.9	12.4	Pt.						
144918	U Bootis	2736.8	10.6	M.									
151731	S Cor. Bor.	2671.5	7.6	Ch,	2716.8	7.6	M,	2732.8	7.5	Pt,	2735.9	7.9	E.
153378	S Urs. Min.	2690.7	9.8	Mu,	2718.7	10.8	Pt,	2729.5	10.6	K,	2731.6	11.2	Ro.
154428	R Cor. Bor.	2671.5	6.0	Ch,	2699.7	6.1	L,	2704.7	6.1	L,	2716.8	6.2	M,
		2732.8	6.0	Pt,	2733.8	6.1	Pt,	2734.8	6.1	Pt,	2734.8	6.2	E,
		2735.8	6.2	M,	2735.9	6.1	E,	2735.9	6.0	Pt,	2737.8	6.2	Pt.
154536	X Cor. Bor.	2716.8	9.2	M.									

VARIABLE STAR OBSERVATIONS, January 20 to February 20, 1921—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
154615	R Serpentis	2732.8	7.3	Pt,	2736.8	6.7	M.						
154639	V Cor. Bor.	2716.8	9.1	M,	2733.9	9.0	Pt.						
155823	RS Scorpii	2735.9	10.0	Pt.									
160118	R Herculis	2735.9	*11.9*	E.									
161122c	T Scorpii	2734.9	10.7	Pt.									
161138	W Cor. Bor.	2735.9	8.4	Pt.									
162119	U Herculis	2678.5	7.5	Ch,	2732.8	8.7	Pt,	2735.8	8.4	M.			
162807	SS Herculis	2735.9	12.6	Pt.									
163137	W Herculis	2678.5	10.8	Ch,	2735.8	11.3	M.						
163172	R Urs. Min.	2735.8	10.4	M.									
163266	R Draconis	2663.0	8.5	Ch,	2675.5	7.9	Ch,	2729.6	11.6	Y,	2732.8	10.5	Pt.
		2735.8	10.3	M.									
164055	S Draconis	2735.8	8.7	M.									
164715	S Herculis	2736.8	8.2	M.									
165030	RR Scorpii	2555.5	7.0	Dw.									
165631	RV Herculis	2733.9	13.4	Pt,	2735.9	13.0	E,	2736.8	12.0	M.			
170215	R Ophiuchi	2734.9	9.5	Pt.									
170627	RT Herculis	2737.8	8.9	Pt.									
171401	Z Ophiuchi	2733.9	8.0	Pt.									
171723	RS Herculis	2732.8	8.7	Pt,	2735.8	8.3	M.						
172486	S Octantis	2631.7	9.2	Dw,	2667.7	10.8	Dw,	2677.7	11.5	Dw.			
174406	RS Ophiuchi	2737.9	10.4	Pt.									
175458a	T Draconis	2738.8	11.4	M.									
175458b	UY Draconis	2738.8	*11.4*	M.									
175519	RY Herculis	2662.0	9.5	Ch.									
175654	V Draconis	2738.8	9.8	M.									
175654b	— Draconis	2738.8	6.0	M.									
180363	R Pavonis	2631.7	11.3	Dw,	2668.5	8.3	Dw.						
180531	T Herculis	2662.0	9.6	Ch,	2732.8	9.1	Pt,	2738.8	9.8	M.			
180565	W Draconis	2734.9	11.5	Pt,	2738.8	11.6	M.						
180666	X Draconis	2738.8	11.5	M.									
180911	Nova Ophiu.	2734.9	11.3	Pt,	2737.8	11.2	Pt.						
181136	W Lyrae	2732.8	10.0	Pt,	2735.8	11.0	M.						
182133	RV Sagittarii	2555.5	10.9	Dw.									
182224	SV Herculis	2734.9	9.8	Pt.									
182306	T Serpentis	2734.9	11.6	Pt.									
183225	RZ Herculis	2737.9	12.0	Pt.									
184205	R Scuti	2662.0	6.0	Ch,	2733.9	5.5	Pt,	2734.9	5.7	Pt,	2735.9	5.6	Pt,
		2737.9	5.7	Pt.									
184300	Nova Aquilae	2662.0	8.5	Ch,	2733.9	9.1	Pt,	2734.9	9.0	Pt,	2737.9	9.1	Pt.
185032	RX Lyrae	2734.9	12.3	Pt.									
185634	Z Lyrae	2738.9	11.1	M.									
190108	R Aquilae	2734.9	9.5	Pt.									
190925	S Lyrae	2738.9	11.4	M.									
190967	U Draconis	2738.8	10.8	M.									
191033	RY Sagittarii	2555.5	6.7	Dw,	2558.7	6.9	Dw,	2631.6	6.7	Dw,			
		2660.5	6.8	Dw,	2668.5	7.0	Dw.						
191124	TY Sagittarii	2555.6	12.2	Dw,	2631.6	*11.7*	Dw.						
191350	TZ Cygni	2729.5	10.7	Y.									
191637	U Lyrae	2734.9	11.3	Pt.									

VARIABLE STAR OBSERVATIONS, January 20 to February 20, 1921—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
192928	TY Cygni	2738.9	10.3	M.									
193449	R Cygni	2661.1	10.9	Ch,	2688.0	9.5	Ch,	2708.5	8.2	Sz,	2713.5	7.6	Sz,
		2716.5	7.8	Sz,	2716.5	7.1	Pt,	2738.9	7.4	M.			
193509	V Aquilae	2734.9	9.9	Pt.									
193972	T Pavonis	2555.6	8.6	Dw,	2631.6	10.0	Dw,	2659.7	12.4	Dw,			
		2662.6	11.9	Dw,	2668.5	12.9	Dw,	2698.6	*13.5*	Dw.			
194048	RT Cygni	2661.1	9.4	Ch,	2688.0	7.3	Ch,	2708.5	7.1	Sz,	2713.5	7.1	Sz,
		2716.5	7.2	Sz,	2716.5	7.2	Pt,	2738.9	8.0	M.			
194348	TU Cygni	2716.5	*10.8*	Sz,	2738.9	*11.2*	M.						
194632	χ Cygni	2662.1	11.7	Ch,	2694.2	12.4	Ja,	2738.9	*11.3*	M.			
194659	S Pavonis	2555.6	8.1	Dw,	2631.6	7.0	Dw,	2659.7	7.0	Dw,	2662.6	7.1	Dw,
		2668.5	6.8	Dw.									
194929	RR Sagittarii	2555.6	12.1	Dw,	2631.6	13.3	Dw,	2668.5	12.0	Dw.			
195553	Nova Cygni 3	2563.3	2.8	El,	2564.4	3.1	El,	2565.4	3.3	El,	2566.4	3.4	El,
		2567.3	4.0	El,	2568.3	4.2	El,	2568.4	4.2	El,	2569.4	4.0	El,
		2570.3	4.4	El,	2570.4	4.5	El,	2570.5	4.5	El,	2572.3	4.4	El,
		2574.4	5.0	El,	2575.4	5.0	El,	2576.4	5.1	El,	2578.4	5.3	El,
		2579.4	5.4	El,	2580.3	5.4	El,	2581.4	5.6	El,	2582.4	5.8	El,
		2583.4	5.8	El,	2585.4	6.1	El,	2587.4	6.1	El,	2594.5	7.2	Mt,
		2594.3	7.2	El,	2596.3	7.2	El,	2597.3	7.2	El,	2597.3	7.3	Mt,
		2601.4	7.6	El,	2602.4	7.6	El,	2603.4	7.6	El,	2604.3	8.2	Mt,
		2606.4	7.8	El,	2609.3	8.6	Mt,	2611.3	8.2	El,	2612.3	8.1	El,
		2618.4	9.1	Mt,	2619.3	8.3	El,	2621.3	8.6	El,	2622.3	9.2	Mt,
		2626.4	9.3	Mt,	2627.3	9.0	El,	2629.3	9.0	El,	2635.3	8.7	El,
		2644.3	*9.3*	El,	2646.4	9.4	Mt,	2652.3	9.6	Mt,	2662.5	9.1	Mt,
		2671.3	9.3	Mt,	2680.4	9.4	Mt,	2705.3	9.5	Mt,	2712.3	8.6	L,
		2715.5	8.8	Pt,	2716.5	8.7	Pt,	2718.5	8.9	Pt,	2732.8	9.0	Pt,
		2733.9	9.2	Pt,	2734.9	9.1	Pt,	2735.9	9.5	E,	2737.5	8.9	Pt.
195849	Z Cygni	2716.5	9.5	Pt,	2738.9	10.4	M.						
200715a	S Aquilae	2734.9	9.6	Pt.									
200938	RS Cygni	2671.1	7.5	Ch,	2691.3	7.9	L,	2716.5	7.7	Pt,	2719.3	8.2	L,
		2738.9	8.8	M.									
201139	RT Sagittarii	2555.6	9.0	Dw,	2631.6	11.7	Dw,	2668.5	13.0	Dw.			
201437	P Cygni	2661.1	5.2	Ch.									
201647	U Cygni	2713.5	7.4	Sz,	2716.5	7.5	Sz,	2716.5	7.2	Pt,	2738.9	7.2	M.
202240	U Micros.	2555.6	10.5	Dw,	2631.6	13.2	Dw,	2662.6	13.0	Dw,			
		2668.5	13.5	Dw.									
202539	RW Cygni	2738.9	9.0	M.									
202946	SZ Cygni	2679.5	9.5	K,	2713.5	9.3	M.						
203226	V Vulpeculae	2734.9	8.6	Pt.									
203847	V Cygni	2663.1	*11.8*	Ch.									
204405	T Aquarii	2663.1	*11.0*	Ch.									
205627	RR Capricor.	2555.6	14.0	Dw,	2631.6	*14.0*	Dw,	2668.5	*13.4*	Dw.			
210868	T Cephei	2663.0	8.0	Ch,	2712.4	7.2	L,	2716.5	7.3	Pt.			
212030	S Micros.	2555.6	11.1	Dw,	2631.6	13.4	Dw,	2665.6	10.0	Tp.			
213244	W Cygni	2699.3	6.1	L,	2712.2	5.9	L,	2719.8	6.1	L.			
213843	SS Cygni	2688.0	11.8	Ch,	2691.2	12.0	Ja,	2691.3	*12.2*	L,	2694.2	12.0	Ja,
		2696.2	11.9	Ja,	2697.2	12.0	Ja,	2699.3	12.1	L,	2700.2	11.9	Ja,
		2700.3	11.6	Pe,	2701.2	11.9	Ja,	2706.2	11.9	Ja,	2706.5	*11.0*	K,
		2707.5	12.0	B,	2712.2	11.8	L,	2713.2	*10.0*	L,	2713.5	*11.3*	M,
		2715.2	9.5	Ja,	2715.5	9.1	Pt,	2715.5	8.8	B,	2716.3	8.1	Ja,
		2716.5	8.4	Cl,	2716.5	8.2	Pt,	2716.5	8.5	K,	2717.5	8.3	Pt,
		2717.5	8.5	Y,	2718.2	8.2	L,	2718.5	8.5	Y,	2718.5	8.4	B,
		2718.5	8.3	Pt,	2719.2	8.1	Ja,	2719.3	8.3	L,	2719.5	8.4	Ba,
		2720.2	8.1	Ja,	2721.5	8.7	B,	2727.5	9.0	M,	2729.5	9.8	Y,

VARIABLE STAR OBSERVATIONS, January 20 to February 20, 1921—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
213843	SS Cygni	2729.5	10.0	K,	2733.5	*11.3*	Pi,	2733.9	11.9	Pt,	2734.9	11.9	Pt,
		2735.5	11.7	Pt,	2736.0	*11.3*	E,	2736.5	11.8	Pt,	2736.5	11.7	Ba,
		2737.5	11.7	Pt,	2738.9	*11.3*	M.						
214024	RR Pegasi	2707.5	*13.0*	B.									
214247	R Gruis	2555.8	14.0	Dw,	2631.6	13.9	Dw,	2659.7	12.7	Dw,			
		2665.6	11.8	Tp.									
220412	T Pegasi	2718.3	*12.7*	L.									
221948	S Gruis	2555.6	7.0	Dw,	2631.6	10.2	Dw,	2659.7	10.9	Dw,			
		2665.6	11.7	Tp,	2698.6	12.5	Dw.						
222439	S Lacertae	2691.3	8.3	L.									
223462	T Tucanae	2631.6	8.9	Dw,	2659.7	8.7	Dw,	2665.6	8.7	Tp,	2669.7	9.2	Dw,
		2696.6	11.0	Dw,	2696.6	10.9	Tp,	2698.6	10.8	Dw.			
223841	R Lacertae	2691.3	12.4	L,	2713.5	*11.8*	M.						
225914	RW Pegasi	2713.5	10.8	M,	2718.5	11.3	Y,	2729.5	10.2	Y.			
230110	R Pegasi	2691.2	10.6	Ja,	2716.5	8.8	Pt,	2719.2	8.5	Ja.			
230759	V Cassiop.	2700.3	11.5	Pe,	2716.5	11.8	Pt,	2718.6	12.3	B,	2728.7	11.2	Bs,
		2731.8	*11.4*	Bs,	2733.5	11.7	Pi.						
231425	W Pegasi	2712.3	9.4	L.									
231508	S Pegasi	2707.5	11.8	B,	2716.5	12.3	Pt.						
232746	V Phoenicis	2631.6	11.5	Dw,	2659.7	12.9	Dw,	2665.7	13.3	Tp,			
		2667.7	13.5	Dw,	2669.7	13.3	Dw.						
233335	ST Androm.	2675.2	10.0	Ch,	2716.5	10.0	Pt,	2727.5	10.0	M,	2733.5	9.5	Pi,
		2738.5	9.1	Gd.									
233815	R Aquarii	2663.1	6.9	Ch,	2688.1	6.8	Ch,	2716.5	7.6	Pt.			
233956	Z Cassiop.	2733.5	*12.6*	Pi.									
235150	R Phoenicis	2631.6	10.1	Dw,	2665.6	12.9	Tp,	2667.7	13.2	Dw,			
		2669.7	13.1	Dw,	2696.6	14.0	Dw,	2696.6	14.0	Tp.			
235209	V Ceti	2712.3	*11.4*	L,	2718.2	*12.7*	L.						
235350	R Cassiop.	2715.5	11.0	B,	2727.8	11.2	Bs,	2733.5	11.8	Pi.			
235525	Z Pegasi	2700.2	12.6	Ja	2716.5	11.9	Pt.						
235855	Y Cassiop.	2733.5	11.1	B.									
235939	SV Androm.	2716.5	12.2	Pt,	2717.5	12.0	Y,	2733.5	*12.0*	Pi.			

Total Observations: 1,068. Stars Observed: 259. Observers: 29.

Min. Charts of these and other regions may be obtained from Mr. A. C. Perry upon request. Those observers who are coöperating in the nova search are requested to include the data of these observations in their monthly reports to Harvard Observatory.

Owing to the fact that the undersigned finds it necessary to pursue his studies the coming year in England, Miss Arville D. Walker has been chosen to act as Recording Secretary in his absence. Miss Walker is a member of the staff of the Harvard College Observatory, and the Association is indeed fortunate, in view of the efficient service which she will be in a position to render. The thanks of all are due to Miss Walker for her generosity in undertaking these arduous duties. Observers are requested therefore to send their reports *in duplicate*, one copy on the blanks of the Harvard College Observatory and one copy on the new A. A. V. S. O. blanks; both copies can be sent under the same cover to the A. A. V. S. O., Harvard College Observatory, Cambridge 38, Mass., U. S. A. This change should become effective for foreign observers with all reports mailed after May 1, and for observers in this country with all reports mailed after June 1, 1921.

The following members contributed to this report: Messrs. Bancroft, "Ba,"

Barns, "Bs," Bouton, "B," Chandra, "Ch," Clement, "Cl," Dawson, "Dw," Eaton, "E," Ellsworth, "El," Godfrey "Gd," Hall, "Hl," Janczewski, "Ja," Kimball, "K," Lacchini, "L," McAteer, "M," Merton, "Mt," Mundt, "Mu," Peltier, "Pt," de Perrot, "Pe," Peters, "Ps," Pickering, "Pi," Potter, "Po," Reesinck, "Rk," Rhorer, "Ro," Schwartz, "Sz," Tapia, "Tp," Watson, "Pw," Yalden, "Ya," Yont, "Yo," and Miss Young, "Y."

HOWARD O. EATON,
Recording Secretary.

GENERAL NOTES.

Professor Sherburne W. Burnham, well known throughout the world because of his work in developing double star astronomy, died at his home in Chicago on the morning of March 11. He had been in feeble health for some time, and about three weeks before his death suffered an injury in a fall from which he could not recover. He was 82 years old on the twelfth of last December.

A full account of his life and work will be published in POPULAR ASTRONOMY in the near future.

Mr. Alfred Rordame, of Salt Lake City, Utah, has written that he is now using the 9-inch Clark refractor of the University of Utah in photographing the planet Venus. He states that on some of his negatives there is evidence of the presence of snow caps at both poles, showing the inclination of the planet's axis to be not far from the vertical.

Sr. D. Tomás de Azcárate, director of the Marine Observatory of San Fernando, Spain, since 1903, died on January 25, 1921 in his seventy-second year.

Bernhard H. Dawson has been appointed Acting Director of the La Plata, Argentine, Observatory to fill the vacancy caused by the resignation of the former director, F. Aguilar.

Sidereal Messenger, Vol. I, is desired for completing a file of this publication. Anyone having this volume and wishing to dispose of it is requested to write to the editor of POPULAR ASTRONOMY.

Distance traveled by an Octogenarian.—Mr. Albert J. Canney, of Seattle, Wash., who is just eighty years old, has made the observation that it would require five thousand years for a rifle ball with a velocity of one-half mile per second to go as far as a man who is 80 years old and has lived at the 42° of latitude, has been carried simultaneously by the earth's diurnal rotation, its annular revolution around the sun and the movement of the solar system through space, since his birth.

Crab Nebula in Taurus.—The following brief statement, dated March 7, 1921, concerning changes in the structure of the Crab nebula in Taurus has been received from Dr. V. M. Slipher of the Lowell Observatory:

> "Changes in the structure of the Crab nebula in Taurus, Dreyer No. 1952, have been detected here by Lampland on negatives taken with the forty-inch Lowell reflector. Results are based on examinations of fifteen photographs covering an interval of eight years."

The National Academy of Sciences.—The Annual Meeting of the National Academy of Sciences will be held at the United States National Museum, Natural History Building April 25 to 27, 1921. Several features of unusual interest are promised. The Prince of Monaco, who is to receive the Agassiz Medal, will give an address on Monday evening, April 25, on his long continued and highly valued researches in oceanography. On another occasion Dr. W. S. Adams, of Pasadena, will speak of his many years of investigation whereby for the first time the spectrum classification, distances, absolute magnitudes, velocities, and directions of motion in space of nearly 2,000 stars are fully known, so that a new far-reaching view of the arrangement of the stellar system appears.—*(The American Journal of Science,* March 1921.)

Betelgeuse.

O Betelgeuse! O Betelgeuse!
How very old and stale the news
Which comes upon the wings of light
From out the caverns of the night.

Three hundred years or so, they say
Thy light has travelled on its way,
What happened when it left, I trow,
Is more than ancient history now.

I'm glad thy much inflated sphere
Is not particularly near;
That quite a trillion miles or so,
Doth separate me from thy glow.

O Betelgeuse! O Betelgeuse!
I had an old time fit of blues
When first I heard the wondrous tale,
At which the noon-day sun grew pale.

But now I do not fear at all
Thy most stupendous fiery ball;
Thou art so far away in space
I'll never meet thee, face to face.

A child, I wondered at thy light
Far up above the world so bright;
But now I wonder more by far
Because I know just what you are.

Ivy, Virginia. F. W. Neve.